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Forecasting the probability distribution of US harvest time average corn prices

Daniel Michael O'Brien
Iowa State University

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**Forecasting the probability distribution of U.S. harvest time
average corn prices**

O'Brien, Daniel Michael, Ph.D.

Iowa State University, 1993

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Ann Arbor, MI 48106**

Forecasting the probability distribution of
U.S. harvest time average corn prices

by

Daniel Michael O'Brien

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Department: Economics
Major: Agricultural Economics

Approved:

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~~In Charge of Major Work~~

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For the Graduate College

Members of the Committee:

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Iowa State University
Ames, Iowa

1993

DEDICATION

To the Lord, Who has blessed me with salvation through Jesus Christ, as well as with a good mind and the opportunity to serve others.

and

To my parents, Michael and Donna O'Brien, who have provided for me and continually supported me throughout my life.

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ABSTRACT

A procedure is developed which provides preharvest forecasts of the probability distribution of U.S. harvest time average corn prices. Crop-weather models are used to estimate the relationship between corn yields, technology trends and weather conditions for seventeen corn producing regions in the U.S. Corn Belt at monthly intervals throughout the growing season. Probability distributions of U.S. corn production forecasts are derived based on historic production forecast accuracy. To produce price forecasts, a corn price model is estimated from corn supply and demand information available to the market at harvest time. Forecasts of the probability distribution of U.S. harvest time average corn prices are calculated from corn production forecast distributions and current USDA projections of beginning stocks, feed use, exports, and old crop total corn usage.

CHAPTER 1. INTRODUCTION

The preharvest grain marketing decisions of farmers are heavily influenced by forecasts during the growing season of grain production and new crop prices. Most preharvest forecasts of corn production are given in the form of point estimates, while preharvest forecasts of new crop grain prices are given as either price ranges or point estimates. The probabilities associated with alternative grain production and price forecast scenarios are usually not identified. When preharvest probabilities of various corn market outcomes are identified, they are often based on rudimentary statistical analysis of historic weather conditions and the analyst's intuition rather than accepted econometric methods. As a result, the accuracy of such forecast probabilities is questionable and of limited use to managers involved in grain marketing.

Crop-weather models measuring the effect of technology trends and weather factors on corn yields have been developed by Butell and Naive (1978), Willimack and Teigen (1985), Thompson (1986), Westcott (1989), Teigen (1991), Babcock and Foster (1991) and Kaylen and Kuroma (1991). Thompson (1986), Westcott (1989) and others have developed models for use during the growing season to forecast subsequent corn yields. Extensive estimation of pre growing season crop yield probability distributions has been carried out by Day (1965), Mowers, Fuller and Shrader (1981), Gallagher (1987 and 1988), Fackler (1989), Fackler and Young (1991), Moss and Shonkwiler (1991) and Moss and Boggess (1992). But there has been no attempt to use crop-weather models to forecast the probability distribution of corn yields conditional on weather up to a point in time during the growing season. Plant process models have been used for this purpose by Krog (1988) and Kunkel

(1991). Whether yield forecasts derived from crop-weather models are more accurate than forecasts from plant process models is a matter of disagreement among crop yield model researchers.

A number of structural models of grain market supply and demand have been developed for use in forecasting and policy analysis. Examples are found in Houck and Subotnik (1972), Chen (1977), Arzac and Wilkinson (1979) and Westhoff, et al. (1990). The reduced form equations from these multiple equation systems offer a guide for the development of single equation applied price forecasting models. Such single equation price models have been developed by Wisner (1977), Van Meier (1983), Westcott, et al., (1985), Westcott and Hanthorn (1987), and Baker and Menzie (1988). Shonkwiler and Maddala (1991) and Holt (1992) utilized a switching regressions, rational expectations approach to model grain markets that are alternatively in equilibrium and disequilibrium. Both approaches have been used to obtain average price forecasts for specified periods of time, but not to derive the probability distribution of forecast average prices. No method has been developed for using weather-conditional grain production forecast probability distributions in grain price models to calculate average grain price forecast probability distributions.

The objectives of this dissertation are a) to develop a method for forecasting the probability distribution of U.S. corn production conditional on weather during the corn growing season, b) to estimate the response of U.S. harvest time average corn prices to changes in U.S. corn production and other supply and demand factors, and c) to develop a technique for using the production forecast distributions and the price responsiveness estimates together to calculate U.S. harvest time average corn price forecast distributions.

To accomplish this, a) regional yield forecasting models are developed and estimated utilizing available weather data, b) production forecast distributions from regional crop-weather models are aggregated together to calculate a U.S. corn production forecast distribution, c) a U.S. harvest time average corn price forecasting model is estimated, and d) the U.S. corn production forecast distributions and the harvest time average corn price model are used together to estimate the U.S. harvest time average corn price forecast distribution. The first part of this study will involve extending the crop-weather model developed by Thompson, where technology trends, temperature, moisture and the stage of crop development are primary factors affecting crop yields.

Following this introduction, the relevant literature on modeling grain yields and prices is reviewed. The estimation procedures used for the regional crop-weather models are then discussed, along with the method for deriving preharvest crop production forecast probability distributions. Next, the harvest time corn price model estimation and forecasting procedure is presented. A discussion of the research findings and suggestions for future research conclude this dissertation.

CHAPTER 2. LITERATURE REVIEW

Crop Yield Forecasting Models

Crop-weather models

The crop-weather modeling approach in this research is an evolution of the modeling approach used by Thompson (1986). Thompson estimated a corn crop-weather model for the period from 1891 to 1983. His purposes were to determine the impact of changes in climate and weather variability on corn production and to estimate the effects of departures from normal weather on corn yields. His model was estimated individually for five major Corn Belt states -- Illinois, Indiana, Iowa, Missouri, and Ohio. The multivariate quadratic equation estimated by Thompson is:

$$Y = a + b_j * D_j * TREND + c * X(i) - d * X(i)^2$$

where:

Y = Corn yield

D_j = Dummy variable for technological trends during different time periods
(j = 1 => 1930-1959; j = 2 => 1960-1972; j = 3 => 1973-1983)

TREND = Technological trend

X(i) = Weather variables (departures from normal)

i = 1: Preseason precipitation Sept-June

= 2: June temperature

= 3: July rainfall

= 4: July temperature

= 5: August rainfall

= 6: August temperature

Varying rates of technological change during the 1930-1983 time period were represented using time varying trends. Separate technical trends were estimated for the 1930-1959, 1960-1972, and 1973-1983 time periods. The state crop-weather models were estimated by ordinary least squares. The R^2 for the regression analyses were: Illinois, 0.97; Indiana, 0.96; Iowa, 0.96; Missouri, 0.93; and Ohio, 0.96. When using this model for forecasting during the growing season, Thompson assumed normal weather for the remainder of the year through harvest. In his analysis of yield trends, Thompson found that the fitted yield trend with normal weather from 1930 to 1959 was higher than actual yields. During this time period, many years were warmer and drier than normal, particularly during July and August. Thompson identified normal weather as the average of conditions from 1891 to 1983. The yields were very close to the trend with normal weather from 1960 to 1972, a period of a steep trend increase in fertilizer use, widespread adoption of single cross hybrids, and increasing plant densities by farmers. Corn yield variability increased noticeably after 1972. Post-1972 corn yield variability was similar to the variability of the 1930s except that there were both unusually low and unusually high yields during the 1970's and the 1980's.

Willimack and Teigen (1985) and Teigen (1991) developed soybean and corn yield prediction models using normalized weather variables. Their purpose was to estimate the effect of growing season weather on crop yields. Teigen's (1991) estimation period was 1950-88 for the corn yield model, while 1989 and 1990 weather data were used to test the model's predictive ability. In six of the states for which the model was tested, the model predicted satisfactorily, while in five other states it did not perform well for 1989 and 1990. Teigen attributed the poor performance to either unusual weather patterns or over responsiveness on the part

of the crop-weather model. Westcott (1989) estimated a U.S. corn yield model dependent on monthly weather during the growing season in the Corn Belt for the 1965-1987 period. His explanatory variables included the percentage of Corn Belt corn acres planted by mid-May, total number of U.S. corn acres planted, average June and average July Corn Belt precipitation, average June and average July precipitation squared, squared average June and squared average July temperatures, an interaction term between the proportion of acres planted by mid-May and monthly June weather measures, a dummy variable for the 1983 drought year, and a yield trend. Westcott's results confirmed the importance of July weather conditions to U.S. Corn Belt corn yields. The author states in a footnote that using monthly averages of weather variables may not capture all the effects of weather on yields because the timing of rainfalls and fluctuation in temperatures within the month are not represented.

Babcock and Foster (1991) used a loglinear model to estimate yields of flue cured tobacco. Their aim was to measure the contribution of new genetic material to changes in per acre yields of North Carolina flue-cured tobacco between 1954 and 1987. Logarithmic transformations of yield data were regressed against a yield trend and monthly average rainfall plus irrigation moisture totals for May, June and July. Log yields were used to minimize yield heteroskedasticity. They concluded that genetic innovations contributed between 20 and 30 percent of the yield increases on research station test plots over the 1954-1987 time period, although recent genetic increases have been small. They found no evidence that a recent policy shift induced any effective change in new variety research. Also, nongenetic technical change had differential regional effects, but no regional differences in genetic contribution were found.

Kaylen and Koroma (1991) used a Kalman filter algorithm and 1895-1988 data to estimate a U.S. corn yield model. Their model incorporated a stochastic trend term and monthly weather indices. The model, its one period into the future prediction errors, and historic weather data were used to generate the distribution of 1989 U.S. corn yields conditional on weather data available just prior to 1989 planting. Actual U.S. 1989 average corn yield results were close to the mean and median yield forecasts. The authors suggested that, for future research, model simulations could be tied to supply-demand models to determine the effects of alternative corn production scenarios on corn usage and prices.

Plant process models

The CERES-Maize plant process model (see Jones and Meyers, 1986) is a user oriented simulation model of maize growth, development and yield. CERES-Maize was designed to simulate the effects of cultivar, planting density, weather, soil water, and nitrogen on crop growth, development, and yield. Krog (1988) investigated the potential use of the CERES-Maize plant process model (PPM) for forecasting state and crop reporting district level corn yields in Iowa. The conjecture of his study was that PPMs utilize a rich source of weather, soil and other information that may produce reliable yield forecasts at a localized level. Plant process model corn yield forecasts were generated at the district and state level for Iowa for the period 1975 through 1984. July 1, August 1, September 1, October 1, and November 1 were the dates of the forecasts. These forecasts were compared to United States Department of Agriculture (USDA) forecasts for the same period. Krog concluded that by itself, at its then current stage of development, the CERES-

Maize PPM was not likely to be a comparable replacement for the district corn yield forecasts that were discontinued for Iowa in 1987 by the USDA.

Kunkel (1992) developed a method for making weekly corn yield predictions by crop reporting district in the mid and eastern Corn Belt using the CERES-Maize plant process model. Actual weather data up to a point in time during the growing season was used in combination with weather conditions for the remainder of the growing season across all years in a historic weather data set to estimate probability distributions of corn yields. Whereas Kaylen and Koroma randomized various historic monthly temperature and precipitation amounts for months within any specific growing year, Kunkel used all weather events occurring in each growing season as one complete observation for simulation purposes. Unlike Kaylen and Koroma's approach, growing season weather conditions were not broken down season monthly or weekly averages or totals for model estimation and forecasting purposes. The various yield predictions, based on actual weather to date and simulated weather conditions for remainder of the growing season for each of the years in the weather data bank, were used together to derive harvested yield forecast probability distributions. The CERES-Maize model relies heavily on assumptions about soil type and crop variety, as do all plant process models, which had led to inconsistent performance in other research (Krog, 1988). Kunkel's corn yield prediction - growth simulation approach allowed for estimation of corn yield forecast probability distributions.

Expert systems and neural networks

Stefanski (1989) produced corn yield forecast distributions using an expert system and crop-weather model simulation procedures. These simulated yield

distributions were then integrated with assumed management practices (with the aid of an expert system shell) to determine crop production risks. A modified version of the soil moisture/stress index model developed by Shaw (1963) was estimated for weather conditions at three locations in Iowa for the years 1960-1986. Then actual weather conditions for 1930-1980 were used in the model to forecast corn yield probability distributions for these locations. Stefanski's use of Shaw's crop-weather model in corn yield simulation is similar to Kaylen and Koroma (1991). In both cases a nonstatistical simulation approach was used to generate yield probability distributions. No statistically based forecast error was calculated. Stefanski found that yield forecast distributions were dependent on farmer's yield goals and soil types. Also, yield distributions were nonnormally distributed and were affected by differing planting dates, hybrid maturities, soil types and spring soil moisture levels.

Uhrig, Engel, and Baker (1991) presented neural networks as an alternative tool for use in crop yield forecasting. Neural networks consist of highly parallel, interconnected, simple processing units. These systems differ radically from conventional computing systems in that no programming is required, and knowledge is stored in the topology of the net and in the connection matrix, rather than explicitly coded in defined data structures. They offer an alternative to rule based expert systems for developing intelligent applications. Computer algorithms allow these systems to learn from examples and generalize this learned knowledge for each unique situation. They provide a method for storing and recovering relational information in symbolic and numeric domains. In this application, neural network software was used on weather data, soil moisture data and a trend yield variable to predict corn yields. The illustration of yield forecasts by the authors

showed a nearly perfect fit for all but the most recent years of the forecast. This leads to a question about whether, in the context of corn yield forecasting, in-sample model estimation errors and out-of-sample forecast errors were portrayed adequately. The authors stated that standard regression equations, although statistically sound, result in large, unacceptable error terms. Although critical of conventional statistically based yield estimation models, this paper offered no alternative measures of model estimation or forecast accuracy from which forecast probability distributions could be derived.

Modeling yield probability distributions

Day (1965) observed that normality or lognormality appeared to be the exception rather than the rule with regard to the probability distribution of field crop yields. His work indicated that the type I (generalized beta) skewed function of limited range is the general case for yield distributions. Using yield data available up to the mid 1960s, Day concluded that positive skewness of yields was the common case. However, more recent evidence shows that distributions of crop yields, especially for U.S. corn, are negatively skewed. The work of Mowers, Fuller, and Shrader (1981) demonstrated that corn production within a crop rotation in northwestern Iowa depended on stored soil moisture at the time of corn planting. A corn-moisture response curve was estimated with preseason stored moisture and a weather index as explanatory variables.

Gallagher (1986, 1987) showed that preseason probability distributions of corn and soybean yields were both negatively skewed. An important aspect of Gallagher's work was the method used to measure the yield potential (i.e., the capacity function) of a crop. The capacity of a crop was represented by a trend or a

more complex function of technical or economic factors. The trend increase in corn yields was characterized by a linear trend for the 1933-1955 period and a logarithmic trend for 1955-1981. Gallagher also noted that a market level yield distribution can have different properties than corresponding individual farm yield distributions. This can occur because yield fluctuation arises from two independent components, one associated with weather patterns common to all locations and the other reflecting local effects such as weather or management practices. The skewness of the microdistribution depends on both the common and local components. However, the third moment of the market distribution is identical to the third moment of the common component. Thus, positively skewed yields at some individual locations and negatively skewed yields for states, regions, or nations may occur simultaneously. This could occur when a local effect is large and positively skewed while the common effect is negatively skewed.

Fackler (1989) and Fackler and Young (1991) studied the use of a stochastic trend in corn yield models and problems in modeling crop yields, respectively. In their discussion of modeling yield distributions and normalizing data, they observed that location and scale (mean and variance) aspects of yield distributions have varied over time. However, the authors found it difficult to tell whether higher order effects (skewness, kurtosis) were time varying. It may be that in their research only scale effects were time varying in yields, so that all higher normalized moments of the yield distribution, including the coefficient of variation, were constant over time. The authors pointed out that there are limits to what can be gained from statistical refinements such as estimation of stochastic trends and nonnormal errors. From a practical perspective, they stated that disaggregation of the regional data between irrigated and nonirrigated crop yields would probably do

more to improve the real world usefulness of the results than reliance on alternative statistical approaches. Irrigation expansion in some regions might well have accounted for convex yield trends for some crops. Their work suggested that very significant gains in estimation were to be achieved by careful attention to the error distribution. The authors said that least squares methods were less desirable than appropriate maximum likelihood methods because these methods were highly sensitive to outliers, particularly at the beginning or end of the sample. A simulation showed that the maximum likelihood method gave far better trend estimates than least squares even though the wrong model was used and there appeared to be some bias in the estimates. Fackler and Young stated several requirements for variability and trend measurement methodology. First, this methodology must accommodate varying trend patterns over different crops and regions, especially in the case of nonlinear trends. Second, it must accommodate potentially nonnormal, skewed error distributions. The authors state that maximum likelihood estimation approaches under appropriate error distribution assumptions provide a means of handling this problem. Third, it must provide a method of adjusting for potential heteroskedasticity in error distributions over time. Fourth, it must accommodate potential autocorrelation in the error distribution over time.

Moss and Shonkwiler (1991) discussed two areas of yield estimation, the use of a stochastic trend, and nonnormal error distributions. In their work the estimated errors from the stochastic trend model failed a test for normality. Thus, a transformation was used to model the nonnormality of errors within the stochastic trend model. Estimation was carried out using a maximum likelihood estimation procedure with the hyperbolic sine transformation. Normality of the error distribution was assumed as a special case. The results indicated that both the

stochastic trend and nonnormality in the error distribution were important in model estimation. Further, simulations of corn yields using estimated parameter values indicated that failure to recognize the nonnormality of model residuals tended to cause an overstatement of the variability of crop yields over time.

Swinton and King (1991) showed that many robust estimation techniques fail to give more reliable coefficient estimates than OLS in a simple regression of yields on a linear time trend when an extreme value of the dependent variable lies at the end of a yield time series. This analysis was carried out on actual farm level data. A Monte Carlo study found OLS to generated more accurate coefficient estimates than trimmed least squares, the best performing of six robust estimation methods tested. The use of the DFBETAS regression diagnostic was recommended as a method to determine whether the influence of an extreme outlier was strong enough that it should be eliminated from a data set. DFBETAS measures the difference between estimates for the j 'th coefficient with and without the i 'th observation, as standardized by the coefficient standard error.

Moss and Boggess (1992) presented two approaches for modeling nonnormal correlated random deviates. The authors stated that it has been typically hypothesized that crop yields become more normal as they are aggregated over regions. To examine the pooling properties of yields, corn yield data collected for three counties in Florida for 1961-1989 was detrended using ordinary least squares and a linear trend. The residuals were then tested for normality. Corn yield estimation residuals in two of the counties exhibited nonnormal yields. The third counties' yield prediction errors could not be distinguished from a normal distribution. The yield data was then pooled to represent regional data. Preliminary evidence suggested that aggregation of yield data (from the county

level to the regional level) eliminated nonnormality from the sample. In their study they found state level corn yields to be normally distributed.

Nelson and Preckel (1989) fit corn yields to a beta distribution which was conditional on fertilizer application over time using a two-stage maximum likelihood estimation procedure. They suggested that the conditional beta distribution has the advantage of flexible skewness which the normal, log-normal, exponential and gamma distributions do not. Their results showed that corn yield distributions conditional on fertilizer were negatively skewed. Babcock (1990) used a similar estimation approach in his research on acreage decisions under marketing quotas and yield uncertainty for peanut production in North Carolina. Babcock's results also indicated negative skewness of the crop yield distribution.

Heteroskedasticity

Yang, Koo, and Wilson (1991) provided evidence that heteroskedasticity in crop yield models was likely due to model misspecification. They stated that potential sources of heteroskedasticity should be included in models rather than making standard assumptions on the error structure. Their results also suggested that the GARCH specification would be useful for modeling heteroskedasticity when the sources are not identified. In their discussion, Yang, et al. pointed out that conventional use of linear time trend or time series models could partly explain the variation of crop yields. However, heteroskedasticity may result from model misspecification, most likely due to omitted variables, or incorrect functional forms (Judge et al., 1988). Offut et al. (1987) found that the variability of corn yields around a trend increases over time, but inclusion of explanatory weather variables was likely to remove the heteroskedasticity. Yang, et al. said that an appropriate way

to model heteroskedastic yields was to incorporate possible sources of heteroskedasticity as a priori information. If analysis failed to identify those sources, it would be important to determine how the variance behaves over time in order to standardize the data. In their results, Yang, et al. found that the econometric wheat yield models which incorporated planted acres and climatological variables along with a time trend resulted in i.i.d. normal errors for durum and hard red spring wheat. These models were heteroskedastic when only the time trend was considered as an explanatory variable. Conventional use of OLS for estimation was acceptable for the yield data that was not heteroskedastic.

Crop yield prediction model literature summary

The two most common types of crop yield prediction models that use weather factors as explanatory variables are the crop-weather models and the plant process models. There is a fundamental difference between the approach used in each model type. The crop-weather models assume that yields are functions of technology trends and deviations from normal weather conditions. The PPMs build their yield projections from a zero yield base, assuming that the various processes of a plant work together in a cumulative manner to bring about a final crop yield.

Plant process model yield forecasts tend to be less accurate than crop-weather model forecasts because of the PPMs' "base-zero cumulative plant process" approach to yield prediction. A 10% forecast error for PPMs, starting from zero on a yield scale, is much greater than a 10% prediction error for a crop growth model whose beginning yield estimate consists of a point determined by the combination of a constant and a technology trend. As a result, the "constant-trend-normal weather

deviations" approach taken by crop-weather models results in more accurate yield forecasts.

Aside from forecasting accuracy, each type of model has strengths and weaknesses. No consensus has emerged regarding the best representation of crop-weather models. Many different functional forms and explanatory variables have been used in the crop-weather model literature. Research efforts are now focusing on overcoming problems that the crop-weather models have encountered in representing technology trends, in assumptions regarding the distribution of model estimation errors, in dealing with yield heteroskedasticity (changing yield variability over time), and in determining the appropriate period of time to use in representing weather-related explanatory variables. Plant process models rely heavily on site specific information such as soil type and crop variety in yield determination. The data requirements for producing accurate forecasts from plant process models cause problems when PPMs are used to project crop reporting district or state level yields over various soil types and crop varieties.

There are several criteria which should be considered when selecting a model or method for prediction of corn yields. The purpose for which the model is being used is the most important selection criteria. As discussed above, some models are better suited for forecasting applications (i.e., crop-weather models), while other types of models are better suited for experimental uses (i.e., plant process models). The net economic value of crop yield forecast information to a decision maker is also important. The difference between the decision maker's expected utility with and without the forecast is the net economic value of the yield forecast. In turn, the net economic value of a yield forecast equals the difference between the benefits gained from the forecast and the costs of obtaining it. The benefit of the yield

information depends on its usefulness to the decision maker. Farmers would benefit from farm level preharvest yield forecast information. Farm specific yield forecasts together with the national grain price forecasts would help them in making preharvest forward pricing and financial management decisions. It is commonly assumed by economists and agronomists that there is a low correlation between individual farm and national average corn yields. Therefore, the primary value of national yield, production, and price forecasts for a farmer will come from improved price forecast information. Agribusiness and government policy analysts are more likely to benefit from district and national production forecast information than farmers are. The cost to obtain the yield information will depend on the availability and form of the yield and weather data as well as the expense in terms of money and human resources of making a forecast with the model. These values could be analyzed in an expected utility context or in the manner described by Antonovitz and Roe (1988).

Another factor to consider in forecasting model selection is the accuracy of the prediction model. If the probability distribution of a forecast is so widely dispersed that little useful information is provided to decision makers, then the value of the forecast may be less than the value of the resources used to obtain it. Factors that may affect the forecast accuracy of a crop-weather model are the functional form used, structural change in the yield determining process over time due to changing plant genetics or production practices, the choice of model explanatory variables, and the assumptions made about the distribution of the error term and the forecast dependent variable. Geographic adaptability of a model is another factor to consider, especially if the model is to be estimated for climatologically diverse crop production regions. Is a crop-weather model such as

the Thompson model applicable to geographic units with varying agronomic conditions and weather patterns? Also, will the inclusion of irrigation in the western Corn Belt affect the relative importance of precipitation related variables and forecast accuracy? The size of the geographic area for which the model is estimated affects forecast accuracy. When crop-weather models such as Thompson's (1986) are estimated with regional, state and national level data, they tend to give accurate forecasts of region wide average yields. However, their forecast accuracy diminishes when they are estimated for smaller geographic areas such as a farm or an individual crop reporting district.

Commodity Price Forecasting Models

Structural models

The structural simultaneous equations models of agricultural markets discussed below have been used mainly for policy analysis purposes rather than applied commodity price forecasting. The dynamic supply and demand model of the market for U.S. soybeans and their products developed by Houck, Ryan, and Subotnik (1972) is an acknowledged forerunner of the comprehensive structural commodity price models now in use. Data from 1946-1967 were used to empirically model the U.S. soybean market. The model features simultaneous adjustment across markets within crop years and sequential adjustments over time to changing economic conditions.

Chen (1977) discussed the structure and specification of the Wharton Agricultural Model. The Wharton Agricultural Model was a short term econometric forecasting model, useful for quarterly forecasts of supply, demand, and prices of individual farm commodities and for the determination of farm income and

expenditure flows. As a simulation instrument, the impacts of varying weather conditions, government farm programs, farm commodity exports, world crop production, and macroeconomic policy could be analyzed. This model is one of the few examples in the agricultural price determination literature where a commodity price model explicitly accounts for the probabilities of alternative crop yield and production outcomes in the set of explanatory variables. The effects of varying weather conditions on crop production were modeled through a multistage impact analysis of acreage, yield, and production throughout the planting, growing and harvest seasons. The price determination formulation followed Adams and Behrman (1979) who treated stock/demand ratios in a nonlinear fashion as a principal explanatory variable in price equations. As the stock/demand ratio approached the minimum historical level, the impact on price increased rapidly.

Arzac and Wilkinson (1979) presented a quarterly econometric model of U.S. livestock and feed grain markets. Feedgrains other than corn were omitted from the model because of the dominant position of corn in the U.S. feedgrain market and the high correlation of prices among the alternative feedgrains. The corn price was determined as a function of commercial stocks, current exports, and seasonal influences. Corn exports were treated as exogenous, being determined by factors outside the model.

In documentation for the FAPRI model of the U.S. grain sector, Westhoff et al. stated that "Most models of the U.S. crops sector have either exogenized U.S. exports or used a single equation approach to estimating foreign demand for U.S. commodities. A variety of approaches have been used to estimate U.S. export demand (e.g. Bredahl, Womack, and Matthews (1978); Westhoff and Meyers (1985)), but none of the single equation approaches has been satisfactory. Because demand

for U.S. exports depends upon all the factors affecting supply and demand in all other exporting and importing countries, it is very difficult to identify the set of independent variables to include in a single estimated equation." (Westhoff, Baur, Stephens, and Meyers, 1990, p. 6). For all commodities in the FAPRI model, market prices were determined by iterative processes which equated supply with demand for all commodities until the overall model converged to a stable solution. The FAPRI model assumed that for every 100 million bushel change in corn supplies, U.S. cash corn prices responded with a \$0.10 change per bushel in the opposite direction. Final solutions were derived by taking this corn price impact multiplier into consideration simultaneously with impact multipliers and quantity changes in other variables, and then proceeding through a number of iterations until the system converged to a solution. Because of this iteration technique, the final impact on corn prices of a 100 million bushel change in U.S. corn supply in the FAPRI model was generally less than the initial \$0.10 per bushel response.

Applied price forecasting models

Most applied price forecasting models are single equation models. Reduced forms for the endogenous price variables in multiple equation structural models provide guidelines for choosing explanatory variables for inclusion in single equation forecasting models.

Wisner (1977) presented an intuitive, applied approach for forecasting grain prices which primarily relied on observation of market supply and demand fundamentals. Based on a consensus of pre-1977 research findings, Wisner assumed that for each one percent change in total U.S. corn supplies, corn prices would

change in the opposite direction by two percent, assuming all other corn market influencing factors remained unchanged.

Van Meir (1983) showed a relationship between ending stocks as a percent of use and deflated average cash corn prices for 1967-81. He concluded that when ending stocks increased to historically high levels (i.e., 24 or 25 percent of use) corn prices responded by moving downward. Conversely, if corn ending stocks declined below 20 percent of use, corn prices tended to move sideways or higher, and were likely to be above the prevailing farm program loan rate.

Westcott, Hull and Green (1985) studied the relationship between quarterly corn prices and corn stocks. Their approach of relating quarterly prices to ending stocks was derived from a disequilibrium model where ending stocks cleared the market as a residual. The hyperbolic functional form was used in price model estimation.

Westcott and Hanthorn (1987) analyzed the impact of PIK certificates upon the U.S. corn market. To link the changes that would be caused by PIK certificates in corn supply, demand, free stocks, and non free stocks to prices received by farmers, the authors postulated that the level of cash corn prices was related to the ratio of corn free stocks to corn usage. The price determination equation used here was essentially the same as in Westcott, Hull and Green (1985).

Baker and Menzie (1988) used ending stocks as an explanatory variable in a corn price equation for 1973-1984. An exponential functional form was used to reflect the price floor effect of the loan rate.

Price flexibilities and elasticities

The estimation and use of price flexibilities in agricultural forecasting models and their relationship to price elasticities was discussed by Waugh (1964), Houck (1965, 1966), Miller, Capps and Wells (1984), Dorfman, Kling, and Sexton (1990) and Tomek and Robinson (1990). The later work of Miller et al., and Dorfman et al., dealt with the estimation of confidence intervals for price flexibilities. While considering alternative methods of confidence interval estimation, both affirmed the use of a method originally developed by Fieller (1932). With the Fieller method, exact confidence intervals can be produced for price flexibility estimates using straight forward calculations.

Gardiner and Dixit (1987) discussed factors that affect the price elasticity of export demand. Their report also examined how the adjustment period, government policies, domestic structure of trading countries, and export market shares affected export demand elasticity measures. Recent estimates of the elasticity of export demand for selected agricultural commodities were presented. Four alternative methods of estimating export elasticities were discussed: the direct, synthetic, calculation and simulation methods. In direct estimation, the reduced form of the excess demand function facing an exporting nation is directly estimated using econometric methods. Only a small subset of all possible explanatory variables are used in direct estimation of export demand relationships because of various methodological problems (degrees of freedom, multicollinearity, and missing data). Direct estimation generally is thought to lead to biased parameter estimates (Kmenta, 1971, pp. 393-395). Since the elasticity of export demand is defined only for a particular point on the excess demand curve, the impact of a price change is accurately measured only for a small movement around that point. The

elasticity estimate will vary for a movement along the excess demand curve as well as for a shift or a change in the shape of the curve. The synthetic method of export elasticity estimation has been used in constructing a number of agricultural policy simulation models at the USDA and elsewhere. This method is based on a review of elasticities reported in other studies and knowledge about the commodity market under study. The synthetic method relies on other research findings, causing the accuracy of its estimates to be dependent on the accuracy of previous export elasticity research findings. The calculation method is based on Yntema's formula for estimation of export elasticity, and according to Gardiner and Dixit is not as relevant to the issue of price flexibility estimation. The simulation method involves obtaining dynamic price elasticities from a multiple equation model of a commodity market. The model used in this method might be a U.S. commodity market model including a single export demand equation, or a multiple region trade model in which the net trade of all trading countries determines U.S. exports.

Carter and Gardiner (1988) presented a collection of papers given at the 1987 IATRC symposium on Elasticities in International Agricultural Trade. The papers presented at this conference addressed a number of theoretical and empirical issues related to estimation, interpretation, and application of elasticities in international agricultural trade. One conference emphasis was on how the estimation method used affects export demand elasticity estimates. One general observation was that direct estimation tends to yield relatively low elasticity estimates, whereas synthetic estimation yields high estimates. Consensus estimates usually set export demand elasticities somewhere between the results of the direct and synthetic approaches.

Switching regressions price models

Shonkwiler and Maddala (1991) presented a dynamic disequilibrium model for the U.S. corn market. The disequilibrium model presented was described in Maddala (1983, pp. 326-334) where, because of controls on prices, the market is sometimes in disequilibrium (if controls are operative) and sometimes in equilibrium (if the controls are not operative). Whether the market is in equilibrium or in disequilibrium is determined endogenously (by factors not considered in the model) because the external control on price is an endogenous variable. In the U.S. corn market, the control is operative when the local cash price for corn is hindered from going lower by the effective government loan rate for corn, and is not operative when the price is above the local effective loan rate or at the same level as the loan without being constrained from going lower. For estimation purposes, the authors used a technique similar to a switching simultaneous equation model with endogenous switching occurring between equilibrium and disequilibrium market situations. The sample observations were partitioned into two sets, one set of observations for which prices were constrained by the loan rate, and the other set of observations for which they were not. For the first set, an equilibrium model was used in which the market clearing corn price was derived by equating supply and demand factors without being affected by the government loan rate. For the second set, a disequilibrium model is used in which the price is set equal to the loan rate in both the demand and supply equations. Shonkwiler and Maddala derived rational expectations for the explanatory variables (i.e., the supply and demand shifters) using equations in which each of the demand shifters were forecasted as a function of their own lagged values. The rational expectations of the supply and demand shifters were used in the model to determine rational expectations price prediction.

Holt (1992) also used a switching regressions approach in a rational expectations model of the U.S. corn and soybean markets. The model used represented a market for a pair of commodities where price supports truncated at least one of the equilibrium price distributions and where producers form expectations about prices via the rational expectations hypothesis.

Price model literature summary

In the multiple equation structural models, the single equation price models, and the switching regressions models, commodity prices can be determined as a function of fundamental supply and demand explanatory variables. When used for price determination the reduced forms of the structural and switching regressions models used explanatory variables similar to those in the single equation price determination models. Prices were a linear function of the explanatory variables in most models, although there were some exceptions. It is noteworthy that, in the rational expectations switching regressions model, values for the supply and demand shifters were determined using individual autoregressive equations, where each of the demand shifters were modeled as functions of their own lagged values. These predicted explanatory variable values were then used in the previously estimated equations to predict the rational expectations equilibrium price. Direct econometric estimation was a preferred approach in the agricultural commodity export elasticity literature cited above. The direct method used in export quantity-commodity price relationship estimation corresponds to the direct econometric estimation methods utilized in many commodity price models.

CHAPTER 3. FORECASTING CORN YIELD AND PRODUCTION

In this study Thompson's crop-weather model is extended in three ways. First, instead of using whole month explanatory variables, disaggregated intramonth weather data is used for the key corn development months of July and August. The impact of weather conditions on corn yields during critical 10 and 20 day time periods in July and August may lead to increased model forecast accuracy. Second, crop-weather models are estimated at monthly intervals throughout the corn growing season, using only known weather information at the time of model estimation. Third, forecasts of corn yield and production probability distributions are calculated from crop-weather models for individual crop reporting districts.

Corn crop-weather models are estimated for the 1974-1991 time period at monthly intervals throughout the corn growing season. July 1, August 1, September 1, and October 1 models are estimated for each of seventeen homogeneous corn production regions throughout the U.S. Corn Belt. The regional crop-weather models are then used to derive crop reporting district level yield and production forecast distributions. The district level production forecast distributions are aggregated together with a non-Corn Belt corn production forecast distribution to form a U.S. corn production forecast probability distribution. Minimum forecast error confidence intervals are estimated, and actual corn production forecast distributions for 1992 illustrate the forecasting procedure.

Crop-Weather Model Data

USDA corn yield and acreage data were collected by crop reporting district for 1972-1992. Monthly rainfall and temperature data were obtained from the climatological data base of the Midwest Climate Service in Champaign, Illinois (Kunkel, 1992). The major corn producing crop and weather districts in Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin are represented. Rainfall and temperature data were also collected for July 1-10, 11-20, and 21-31, and for August 1-10 and 11-31 for these states to improve the manner in which weather conditions during critical corn development periods are represented. Monthly rainfall and temperature data were collected for the western Corn Belt states of Kansas and Nebraska from state climatologists and statisticians. A more detailed breakdown of July and August weather data was not readily available for the western Corn Belt. USDA survey estimates of the percentage of the corn crop planted by mid-May for each state are used to represent planting progress for each of the crop reporting districts within that state.

The 1974-1991 time period was chosen for model estimation because the weather patterns and crop production technology of these years differed from earlier periods. Examining weather data since 1890, Thompson (1986) identified the 1930's as the decade that had the lowest total July and August rainfall. Only one year during the 1930 through the late 1940's time period had what he classified as normal or better corn yields. Thompson also identified the 1956 to 1973 period as a time when simulated corn yields from his model were 95% of normal or better. Fackler (1989) recognized the 1950's and 1960's as periods of unusually favorable weather in the Corn Belt, which experienced no drought conditions between the years 1958 and 1972. Rapid changes in corn production technology occurred during

the 1960-1972 period, with a steep trend increase in fertilizer use, widespread adoption of single-cross corn hybrids, and increases in plant population densities. These factors led to rapid increases in U.S. corn yield per acre. Since the early 1970s there has been a marked increase in the variability of corn yields and growing season weather conditions. U.S. corn yields have continued to increase during the 1970s and 1980s, but at a more moderate rate than during the previous decade. Post-1972 corn yield variability was similar to that of the 1930s except that there were both unusually low and unusually high yields during the 70's and the 80's, while only unusually low yields occurred during the 1930s. Because of these factors, there is a higher likelihood of avoiding heteroskedastic corn yields across the Corn Belt by estimating the model for the 1974-1991 period than if earlier years were also included in model estimation. Figure 1 illustrates the trend increases and changing variability of U.S. corn yields since 1930.

The weather data was normalized for conditions within each crop reporting district. For example, normalization of June rainfall data for the 1974-1991 period for the west central Iowa crop and weather reporting district is carried out by subtracting the district's 1974-1991 average rainfall from the June rainfall for a specific year, and then dividing by the standard deviation of June rainfall for 1974-1991. If the weather data is assumed to be normally distributed, then suppositions about the probability that normalized weather data is ± 1 , ± 2 , or ± 3 standard deviations from average can be made. No formal analysis of the normality has been carried out for the weather data used in this study. Although weather data normality is not formally assumed here, normalization of the weather variables provides an approximate idea of the relative magnitude and expected frequency of weather deviations from normal. Normalization of the weather data also

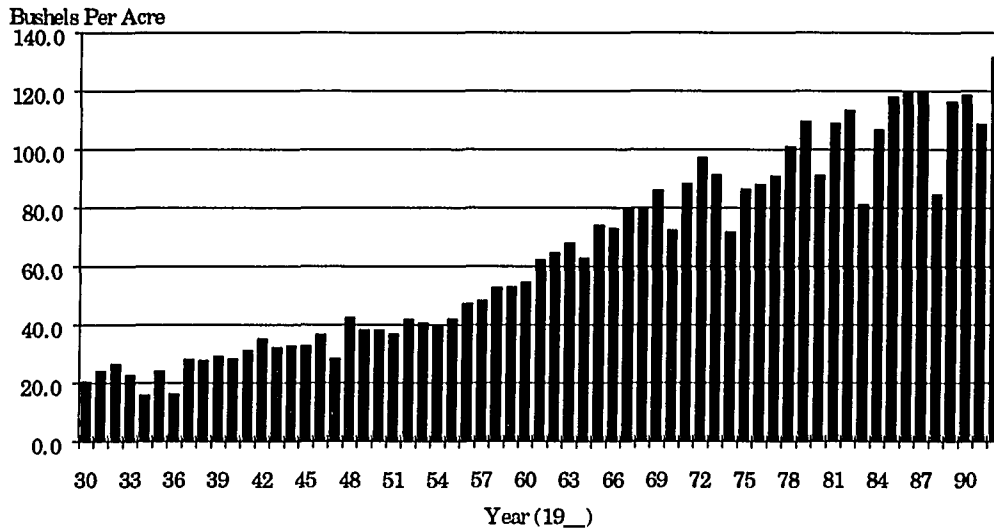


Figure 1. U.S. Average Corn Yields, 1930-1992

facilitates the use of special explanatory variables (i.e., aridity indices) to measure the effects of extreme weather conditions in model estimation.

Determination of Corn Production Regions

Seventeen homogeneous corn production regions are selected from among the major corn producing crop reporting districts in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin. The homogeneous regions or groupings are determined using a combination of three methods: cluster analysis (using Ward's method), the expert opinion of agricultural climatologists and agronomists, and analysis of yield and weather patterns for the various crop and weather reporting districts. An explanation of Ward's method of grouping data based on squared Euclidian distance is given in APPENDIX A. In analysis of yield

and weather patterns, particular emphasis was placed on the similarity of historic yield patterns in adjacent crop production districts along with the degree of similarity among average rainfall and temperature levels during the critical times of crop development. In the western Corn Belt, Kansas and Nebraska are broken into five regions, two irrigated and three nonirrigated.

For nearly all states the crop reporting districts as defined by the USDA are geographically the same as the weather reporting districts defined by the National Oceanic and Atmospheric Administration (NOAA), with the exceptions of Michigan, Missouri, and Ohio. Where the geographic boundaries are not equal, the weather reporting district information was adjusted to represent the geographic boundaries of the crop reporting districts. The only major adjustments due to crop and weather reporting district boundary differences occurred in Missouri, where the northern two thirds of the state was aggregated together to form one large crop district. The specific crop reporting districts included in each region are listed in Table 1. See Figure 2 for a map of the homogeneous nonirrigated and irrigated corn production regions defined in this study.

Crop-Weather Model Specification and Estimation

The dates for which the crop-weather models are estimated during the U.S. corn growing season (July 1, August 1, September 1, and October 1) are chosen to coincide with the forecast dates of the USDA corn yield and production estimates. USDA yield and production forecasts are released approximately 8 to 12 days after the first of each month throughout the growing season. These forecasts represent the government's best prediction of corn yield and production given conditions up through the end of the previous month. However, the August 1 report is the first

Table 1. Description of Homogeneous Corn Production Regions

Region and Description

- 1 Ohio (northeast, eastern, central, and southern)
 - 2 Indiana (northern third and east central) and Ohio (northwest, north central, west central and southwest)
 - 3 Indiana (southern third)
 - 4 Illinois (central and east central) and Indiana (central and west central),
 - 5 Michigan (central and southern)
 - 6 Illinois (northern third and west central) and Iowa (east central and southeast)
 - 7 Iowa (northern third and central) and Minnesota (south central and southeast)
 - 8 Minnesota (northwest, west central and central, and southwest)
 - 9 Wisconsin (northern and middle thirds)
 - 10 Wisconsin (southern third)
 - 11 Iowa (west central and southwest)
 - 12 Illinois (southern), Iowa (south central) and Missouri (northern and central thirds and southeast)
 - 13 Kansas (eastern third) and Nebraska (east central and southeast)
 - 14 Kansas (western and central two thirds)
 - 15 Nebraska (western, northern, northeast, central, southwest, southcentral)
 - 16 Kansas (all except northwest), irrigated
 - 17 Nebraska (all) and Kansas (northwest), irrigated
-

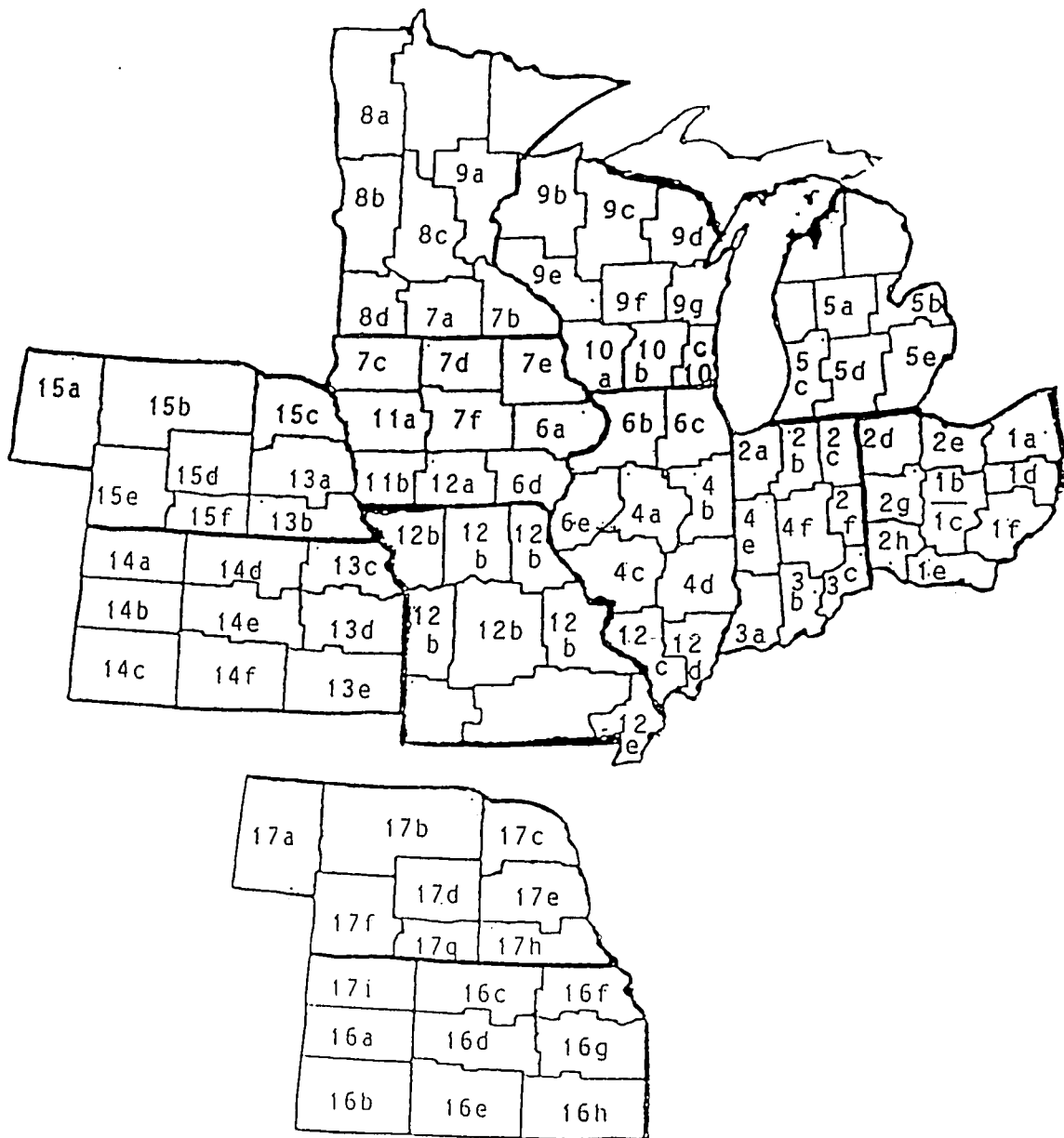


Figure 2. Corn Production Regions

growing season crop estimate based on extensive field surveys.

Each successive monthly model is estimated using only data for weather conditions that have actually occurred up to that point in time during the growing season. When these models are used for forecasting, the use of only known (not projected) weather data allows for the application of unconditional forecasting techniques (see discussion of forecasting techniques given below). The yield forecasts are normally distributed because an unconditional forecasting procedure is used. The explanatory variables for the successive monthly models are listed in Table 2 and definitions of the explanatory variables are included in Table 3. The basic factors expected to affect corn yields are technological advancements (represented by trend), preseason rainfall accumulation, planting date, and growing season temperature and precipitation. The technology trend represents corn yield changes over time caused by improvements in plant genetics, fertility programs, and weed and insect control practices. The most critical stages of corn physiological development are tasseling and silking, both part of the process of corn pollination and seed set (Ritchie et al., 1989). These stages generally occur during July and early August. The eastern Corn Belt intramonth breakdowns of rainfall and temperature effects are designed to represent yield impacting weather conditions during these critical times. After silking, the corn plant moves through the blister, milk, dough and dent stages on to physiological maturity. These stages typically occur from early August through late September or early October, till crop maturity or at the time of the first killing frost. The August and September explanatory variables are intended to measure the yield impact of weather conditions occurring during this time period.

The intramonth breakdown of weather effects during July and August is

Table 2. Corn Crop-Weather Models

July 1 model

$$\text{Yield} = f (\text{Constant, Trend, RainNvMy, PlntMay, TempMay, TempJun, HotJun, RainJun, D##@})$$

August 1 model

Eastern Corn Belt

$$\text{Yield} = f (\text{Constant, Trend, RainNvMy, PlntMay, TempMay, TempJun, HotJun, RainJun, TempeJly, RaineJly, TempMJly, RainMJly, TempLJly, RainLJly, HotDryJly, WetJly, D##@})$$

Western Corn Belt (irrigated and nonirrigated)

$$\text{Yield} = f (\text{Constant, Trend, RainNvMy, PlntMay, TempMay, TempJun, HotJun, RainJun, TempJly, RainJly, HotDryJlym, WetJly, D##@})$$

September 1 model

Eastern Corn Belt

$$\text{Yield} = f (\text{Constant, Trend, RainNvMy, PlntMay, TempMay, TempJun, HotJun, RainJun, TempeJly, RaineJly, TempMJly, RainMJly, TempLJly, RainLJly, HotDryJly, WetJly, TempeAgst, RaineAgst, TempLAgst, RainLAgst, WetAug, D##@})$$

(continued)

Table 2. (continued)

September 1 model (cont)

Western Corn Belt (irrigated and nonirrigated)

Yield = f (Constant, Trend, RainNvMy, PlntMay, TempMay,
 TempJun, HotJun, RainJun,
 TempJly, RainJly, HotDryJlym, WetJly,
 TempAgst, RainAgst, WetAgstm,
 D##@)

October 1 model

Eastern Corn Belt

Yield = f (Constant, Trend, RainNvMy, PlntMay, TempMay,
 TempJun, HotJun, RainJun,
 TempEJly, RainEJly, TempMJly, RainMJly, TempLJly, RainLJly,
 HotDryJly, WetJly,
 TempEAgst, RainEAgst, TempLAgst, RainLAgst, WetAgst,
 TempSep, RainSep, HotDrySep,
 D##@)

Western Corn Belt (irrigated and nonirrigated)

Yield = f (Constant, Trend, RainNvMy, PlntMay, TempMay,
 TempJun, HotJun, RainJun,
 TempJly, RainJly, HotDryJlym, WetJlym,
 TempAgst, RainAgst, WetAgstm,
 TempSep, RainSep, HotDrySep,
 D##@)

Table 3. Definition of Crop-Weather Model Variables

-
1. Trend: Linear time trend, representing technical change
 2. RainNvMy: Total precip. from November (previous year) to May (current year)
 3. PlntMay: Percent of corn planted by mid-May (state level)
 4. RainJun: Total June monthly precipitation
 5. RainEJly: Total July 1st to 10th precipitation
 6. RainMJly: Total July 11th to 20th precipitation
 7. RainLJly: Total July 21st to 31st precipitation
 8. RainJly: Total July monthly precipitation
 9. RainEAgst: Total August 1st to 10th precip.
 10. RainLAgst: Total August 11th to 31st precip.
 11. RainAgst: Total August monthly precipitation
 12. RainSep: Total September monthly precipitation
 13. TempMay: Avg May temperature
 14. TempJun: Avg June temperature
 15. TempEJly: Avg July 1st to 10th temperature
 16. TempMJly: Avg July 11th to 20th temperature
 17. TempLJly: Avg July 21st to 31st temperature
 18. TempJly: Avg July temperature
 19. TempEAgst: Avg August 1st to 10th temperature
 20. TempLAgst: Avg August 11th to 31st temperature
 21. TempAgst: Avg August temperature
 22. TempSep: Avg September temperature
 23. D##@ : Crop reporting district dummy variables, identified by region (##) and CRD (@) where @ is a letter representing the specific district
- Aridity Indices
24. HotJun: Affect of June temps 1.5 normalized units (nzdu's) above average
 Given: $DHot = (\text{ If TempJun} > 1.5, \text{ then} = 1, \text{ otherwise} = 0)$

$$\Rightarrow HotJun = DHot * TempJun$$
 25. HotDryJly: Affect of combined high temps (>.5 nzdu's above avg) and low precip (>.5 nzdu's below avg) for July 11th to 31st, intramonthly data
 Given: $DHot = (\text{ If } [(TempMJly + TempLJly) / 2] > 0.5, \text{ then} = 1, \text{ if not} = 0)$
 $DDry = (\text{ If } [(RainMJly + RainLJly) / 2] < -0.5, \text{ then} = 1, \text{ if not} = 0)$

$$\Rightarrow HotDryJly = DHot * DDry * [(TempMJly + TempLJly) / 2] * (-1) * [(RainMJly + RainLJly) / 2]$$
-

Table 3. (continued)

Aridity Indices (continued)

26. HotDryJlym: Effect of combined high temps ($>.75$ nzdu's above avg) and low precip ($<.75$ nzdu's below avg) for the month of July, monthly data

Given: DHot = (If TempJly > 0.75 , then = 1, if not = 0)

DDry = (If RainJly < -0.75 , then = 1, if not = 0)

$$\Rightarrow \text{HotDryJlym} = \text{DHot} * \text{DDry} * \text{TempJly} * (-1) * \text{RainJly}$$

27. WetJly: Effect of precip $>.5$ nzdu's above avg for July 11-31st, intramonthly data

Given: DWet = (If $[(\text{RainMJly} + \text{RainLJly}) / 2] > 0.5$, then = 1, if not = 0)

$$\Rightarrow \text{WetJly} = \text{DWet} * [(\text{RainMJly} + \text{RainLJly}) / 2]$$

28. WetJlym: Effect of precip $>.75$ nzdu's above avg for July, monthly data

Given: DWet = (If RainJly > 0.75 , then = 1, if not = 0)

$$\Rightarrow \text{WetJlym} = \text{DWet} * \text{RainJly}$$

29. WetAgst: Effect of avg total precip for August 1-10 and August 11-31 being $>.5$ nzdu's above avg, intramonthly data

Given: DWet = (If $[(\text{RainEAgst} + \text{RainLAgst}) / 2] > 0.5$, then = 1, if not = 0)

$$\Rightarrow \text{WetAgst} = \text{DWet} * [(\text{RainEAgst} + \text{RainLAgst}) / 2]$$

30. WetAgstm: Effect of monthly total precip for August $>.75$ nzdu's above avg, monthly data

Given: DWet = (If RainAgst > 0.75 , then = 1, if not = 0)

$$\Rightarrow \text{WetAgstm} = \text{DWet} * \text{RainAgst}$$

31. HotDrySep: Effect of combined high temps ($>.75$ nzdu's above avg) and low precip ($>.75$ nzdu's below avg)

Given: DHot = (If TempSep > 0.75 , then = 1, if not = 0)

DDry = (If RainSep < -0.75 , then = 1, if not = 0)

$$\Rightarrow \text{HotDrySep} = \text{DHot} * \text{DDry} * \text{TempSep} * (-1) * \text{RainSep}$$

incorporated into the eastern Corn Belt crop-weather models in order to capture the impact of the timing of rainfall or temperature events during the critical corn development months. For example, if no rain fell on an area for the first 20 days of July, followed by excessive rainfall during the last 11 days, the monthly precipitation figure may be equal to or above the historic average. However, the crop may have been severely damaged during the first 20 days of the month, diminishing the positive impact of the late month rainfall. This differs from Thompson's model which only used monthly rainfall and temperature variables.

Special effect variables (e.g., aridity indices) are included to estimate the effects of temperature and rainfall extremes on corn yields. The aridity index variables are described in Table 3. These weather extremes may affect yields when they occur alone or in combination with other weather extremes. For instance, either high temperatures or low rainfall alone may not hurt corn yields. However, when these weather conditions occur simultaneously, corn yields may be severely impacted. The criteria for weather extremes are defined in terms of higher positive and/or lower negative values for the normalized weather data. For example, Hot_{Jun} measures the effect on yields of monthly average June temperatures which are greater than 1.5 normalized temperature units above average for the 1974-1991 period. For forecasting purposes, the yield impact of above average June temperatures would be represented by the coefficient of $Temp_{Jun}$ as long as the temperatures were less than or equal to 1.5 normalized units above average. However, if June temperatures rose more than 1.5 normalized units higher than average, then the yield impact would be represented by the coefficient of $Temp_{Jun}$ adjusted by the coefficient for Hot_{Jun} . Thompson's model utilized a quadratic functional form to represent the nonlinear effects of extreme weather conditions.

Using the quadratic form variables in these crop-weather models with their intramonth effects in some cases would lead to a degrees of freedom problem.

Note that for the HotDryJly, HotDryJlym, and HotDrySep variables a (-1) is included in the aridity index equations. This is done in order to reverse the signs of the coefficients. Otherwise the effect on corn yields of combined hot and dry conditions during these time periods would be reported as positive. The expected impact on corn yields from these weather conditions in most areas of the Corn Belt would be negative.

A homogeneous corn production region represents a grouping of crop reporting districts, each with eighteen years of corn yield and weather data. The different crop reporting districts in a region can be thought of as cross sections of the regional data set, with each district or cross section contributing an eighteen year time series of yield and weather data to the regional data set. The number of observations used in model estimation for each region is equal to the number of crop reporting districts in the region multiplied by the number of annual yield and weather observations for each district. If six crop reporting districts are included in a region, each with 18 annual observations (1974-1991), then there would be 108 observations for regional crop-weather model estimation. The econometric advantage of the cross section time series approach is that it provides more degrees of freedom for model estimation. This is especially important in the eastern Corn Belt September 1 and October 1 models, which utilize weather for 10 and 20 day periods during the critical corn development months of July and August. There are not enough years of data for estimation of separate crop-weather models for each crop reporting district without grouping districts together into homogeneous regions represented by cross section time series data sets.

Because of this pooled cross section time series data set structure, dummy variables are used to represent adjustments to the the model constant for each of the subregional crop reporting districts. The regional model intercept is the estimated fixed effect for an arbitrarily chosen base CRD within the region. Assuming there are n crop reporting districts within a region, dummy variables are used to represent adjustments to the constant term for each of that region's $n-1$ other districts. Due to this cross section time series estimation approach, the fixed effect on yields (the constant or the adjusted constant) may vary for the different crop reporting districts within a region. However, the coefficients for all other explanatory variables are identical across the crop reporting districts within a region. In other words, this estimation approach assumes that the model constant may vary across CRDs within a region, but that there is no cross sectional variation in the yield effects of rainfall and temperature. If there is considerable variation in the effect of weather conditions upon corn yields across crop reporting districts within a region, this may limit yield and production forecasting accuracy. Including dummy variables in the model improves explanatory ability, allows for individual crop reporting district level forecasts of corn yields and production, and permits the use of an econometrically acceptable estimation method for the pooled cross section time series data set. A full description of the dummy variable approach to estimating pooled cross section time series models is given on pp. 468-479 in Judge et al. (1988).

Results of Crop-Weather Model Estimation

Ordinary least squares estimates of the July 1, August 1, September 1 and October 1 crop-weather models for each of the seventeen corn production regions are given in Tables 4 through 7.

Table 8 summarizes the significant rainfall variable effects for the crop-weather models by region. Table 9 presents the significant crop-weather model temperature variables by region. Table 10 gives a region by region summary of significant non-weather and aridity index variables for the crop-weather models. The emphasis in discussing these results will be on the factors which were significant in more than one of the monthly models, and especially on those that significantly impacted yields in the September 1 and October 1 model estimates.

In Table 8 the signs of the variable coefficients which are significant at the 5 percent level as well as the monthly models for which they are significant (i.e., for the July 1 (J), August 1 (A), September 1 (S) and October 1 (O) models) are reported. The impacts of extreme rainfall related aridity index variables are included in Table 10. Higher rainfall totals have a positive effect on corn yields in the crop-weather models for almost all the regions and variables. The only major exception is preseason rainfall ($Rain_{NvMy}$) in sections of the middle and eastern Corn Belt (regions 3, 7, 8, and 9). Conversely, preseason rainfall has a positive yield impact in both nonirrigated and irrigated parts of the western Corn Belt (i.e., Nebraska and Kansas, regions 14, 15, and 17). June monthly rainfall ($Rain_{Jun}$) positively effects yields in parts of the middle and eastern Corn Belt from the Iowa/southern Minnesota region to the Indiana/Ohio region, and from southern Wisconsin to southern Missouri (regions 2, 4, 5, 6, 10, and 12).

Table 4. July 1 Crop-Weather Models by Region for 1974-1991

Variable	Region					
	1	2	3	4	5	6
Constant	** 87.13	** 87.56	** 89.67	** 104.81	** 64.24	** 103.29
Trend	** 1.06	** 2.00	** 1.71	** 1.56	** 3.06	* 1.11
RainNvMy	-1.71	-0.31	* -6.43	-4.28	-0.63	-2.10
PlntMay	2.59	1.87	0.10	-1.71	** -4.23	* -6.00
TempMay	-0.74	-0.33	-1.98	1.32	2.40	5.38
TempJun	0.26	-3.08	-2.82	-0.37	** -6.43	-4.85
HotJun	-7.00	2.52	11.26	-1.70	1.62	0.40
RainJun	* 3.56	** 7.43	** 7.62	4.76	** 6.33	** 7.94
D##@	D1a	D2a	D3b	D4b	D5a	D6a
	0.72	-0.96	-10.72	-5.00	-4.82	-2.56
	D1b	D2b	D3c	D4c	D5b	D6c
	7.60	-4.56	-7.10	-2.32	* 6.71	0.18
	D1c	D2d		D4d	D5c	D6d
	4.57	4.06		-10.15	-4.15	-10.41
	D1d	D2e		D4e	D5d	D6e
	5.10	1.12		-8.03	-1.54	-2.43
	D1e	D2f		D4f		
	3.33	-0.11		-4.60		
		D2g				
		0.78				
		D2h				
		2.47				
Constant = CRD#	1f	2c	3a	4a	5e	6b
R ²	0.23	0.34	0.38	0.17	0.78	0.26
Adjusted R ²	0.13	0.26	0.25	0.07	0.75	0.16
Standard Error	13.28	15.95	16.47	21.60	8.48	19.98

* indicates a t test significance of 5 percent

** indicates a t test significance of 1 percent

Table 4. (continued)

Variable	Region					
	7	8	9	10	11	12
Constant	** 85.47	** 69.79	** 77.86	** 79.02	** 71.05	** 86.60
Trend	** 2.96	** 3.22	** 2.42	** 2.36	** 3.82	** 2.15
RainNvMy	** -6.70	-0.72	* -2.54	** -5.80	-1.91	-2.24
PlntMay	** -8.91	* -5.80	** -7.78	** -9.68	* -7.20	-4.36
TempMay	** 5.07	** 8.02	** 5.78	* 4.85	-1.02	3.81
TempJun	-1.96	* -3.75	-1.12	** -7.13	0.03	0.11
HotJun	* -15.96	** -17.83	** -9.59	3.65	-12.59	-10.78
RainJun	-0.11	-1.87	0.07	3.34	** -8.74	** 6.71
D##@	D7a	D8a	D9a	D10a	D11b	D12a
	4.35	** -30.33	** -15.18	4.50	-4.42	* -14.63
	D7b	D8b	D9b	D10b		D12b
	2.30	** -12.82	** -11.55	2.94		** -23.19
	D7d	D8d	D9c			D12c
	* 9.29	-2.66	** -11.41			** -17.63
	D7e		D9d			D12d
	5.60		* -8.87			** -17.66
	D7f		D9e			
	5.21		-1.08			
			D9f			
			-4.24			
Constant = CRD#	7c	8c	9g	10c	11a	12e
R ²	0.64	0.79	0.62	0.71	0.65	0.44
Adjusted R ²	0.59	0.76	0.58	0.65	0.55	0.36
Standard Error	12.61	12.26	11.75	10.97	14.85	17.57

Table 4. (continued)

Variable	Region				
	13	14	15	16	17
Constant	** 55.80	** 43.85	** 46.19	** 76.40	** 105.10
Trend	** 2.26	0.44	** 1.96	** 2.33	** 2.62
RainNvMy	1.78	* 4.21	** 2.95	0.95	1.26
PlntMay	-2.57	2.92	* -3.42	2.32	* -1.86
TempMay	1.43	-0.38	1.96	-0.66	1.35
TempJun	2.97	1.36	-2.48	0.15	1.04
HotJun	-8.75	-0.18	3.52	-3.57	0.83
RainJun	2.70	0.43	-0.42	2.23	-0.44
D##@	D13a	D14a	D15a	D16a	D17a
	4.18	1.10	** -21.72	** 24.23	** -12.40
	D13c	D14b	D15b	D16b	D17b
	-3.02	-2.43	** -14.75	** 40.62	-4.02
	D13d	D14c	D15c	D16c	D17c
	-7.30	-8.16	6.19	** 21.34	** -7.73
	D13e	D14d	D15d	D16d	D17d
	* -14.78	7.87	-7.59	** 25.24	-0.58
		D14e	D15e	D16e	D17e
		0.33	** -17.09	** 32.60	-2.12
				D16f	D17f
				** 17.02	1.00
				D16g	D17g
				** 17.69	4.81
					D17i
					-1.36
Constant = CRD#	D13b	D14f	D15f	D16h	D17h
R ²	0.32	0.19	0.63	0.62	0.76
Adjusted R ²	0.22	0.08	0.59	0.57	0.74
Standard Error	21.82	16.40	12.10	14.60	8.65

Table 5. August 1 Crop-Weather Models by Region for 1974-1991

Variable	Region					
	1	2	3	4	5	6
Constant	** 82.92	** 91.03	** 101.35	** 116.00	** 69.72	** 107.71
Trend	** 1.45	** 1.98	** 1.66	** 1.10	** 2.71	* 1.02
RainNvMy	* -3.05	-1.42	* -3.45	-2.19	-0.56	0.97
PlntMay	-3.02	0.51	-3.45	-0.63	* -3.69	-1.54
TempMay	* 3.96	* 3.43	1.23	3.03	* 2.50	** 7.94
TempJun	** -4.68	** -5.46	** -8.26	-2.77	** -5.68	-2.18
HotJun	0.15	4.09	5.14	5.29	4.18	2.86
RainJun	1.75	** 4.95	1.51	** 4.95	** 5.02	** 9.02
TempEJly	** -8.29	** -7.02	** -5.59	* -4.06	* -2.47	** -7.43
RainEJly	** 3.78	** 4.45	** 7.11	* 3.24	0.21	0.80
TempMJly	** -3.72	** -6.39	-1.35	** -7.85	* -2.41	-3.49
RainMJly	** 6.91	** 7.23	** 8.60	** 10.15	** 4.38	5.51
TempLJly	** -3.40	** -2.70	3.00	0.73	-1.93	1.94
RainLJly	1.80	** 6.37	** 10.12	** 9.78	** 3.95	** 10.27
HotDryJly	** 26.60	-4.56	** -21.25	-8.36	7.89	-7.11
WetJly	* -9.64	** -12.59	** -23.74	** -18.79	** -10.11	-9.26
D##@	D1a	D2b	D3b	D4b	D5a	D6a
	2.20	-0.47	** -12.94	* -8.26	* -5.39	-2.16
	D1b	D2c	D3c	D4c	D5b	D6c
	** 9.07	-4.58	** -10.67	-3.60	* 5.26	-0.83
	D1c	D2d		D4d	D5c	D6d
	* 5.67	4.13		** -11.17	-4.91	* -9.92
	D1d	D2e		D4e	D5d	D6e
	5.41	0.62		* -8.74	-2.37	-2.11
	D1e	D2f		D4f		
	4.42	0.62		-6.47		
		D2g				
		0.45				
		D2h				
		1.45				
Constant = CRD#	1f	2c	3a	4a	5e	6b
R ²	0.72	0.74	0.93	0.75	0.85	0.71
Adjusted R ²	0.65	0.71	0.90	0.70	0.81	0.63
Standard Error	8.36	9.23	6.14	12.31	7.48	13.16

Table 5. (continued)

Variable	Region					
	7	8	9	10	11	12
Constant	** 89.41	** 75.91	** 76.81	** 84.38	** 82.32	** 95.47
Trend	** 2.60	** 2.23	** 2.49	** 1.76	** 2.69	** 1.54
RainNyMy	** -5.36	* -2.87	** -4.00	-2.05	-5.35	0.18
PlntMay	** -4.86	** -5.50	** -4.31	** -5.66	-2.46	0.23
TempMay	* 3.66	** 7.68	* 3.31	** 5.00	0.51	* 4.90
TempJun	** -4.82	-1.49	-1.96	** -8.49	-3.03	0.65
HotJun	** -8.33	** -10.81	** -8.84	* 10.98	* -13.89	-5.99
RainJun	0.31	0.88	0.25	** 5.72	-3.41	** 6.05
TempEJly	* -3.65	2.92	** -5.44	** -4.98	* -7.25	* -3.77
RainEJly	1.01	** 6.65	* 2.17	* -4.11	* 6.42	** 4.31
TempMJly	1.46	** -4.23	* 2.34	-2.31	-3.02	** -5.94
RainMJly	3.20	* 3.82	1.67	** 9.93	* 1.67	* 5.26
TempLJly	0.45	* -2.59	0.56	-1.88	1.08	-2.68
RainLJly	3.78	* 3.74	2.42	2.76	2.15	** 7.41
HotDryJly	* -13.24	* -11.58	5.86	13.58	-4.25	-3.80
WetJly	-1.66	0.43	-0.78	* -12.66	0.66	-8.89
D##@	D7a	D8a	D9a	D10a	D11b	D12a
	5.09	** -26.76	** -15.02	6.01	-4.20	** -14.55
	D7b	D8b	D9b	D10b		D12b
	1.46	** -9.37	** -11.30	4.35		** -23.37
	D7d	D8d	D9c			D12c
	* 8.12	2.77	** -11.47			** -18.90
	D7e		D9d			D12d
	5.20		** -9.24			** -18.16
	D7f		D9e			
	3.69		-0.70			
			D9f			
			-3.98			
Constant = CRD#	7c	8c	9g	10c	11a	12e
R ²	0.75	0.92	0.75	0.85	0.87	0.78
Adjusted R ²	0.70	0.89	0.69	0.78	0.77	0.72
Standard Error	10.89	8.23	10.02	8.79	10.63	11.65

Table 5. (continued)

Variable	Region				
	13	14	15	16	17
Constant	** 64.79	** 42.52	** 48.80	** 78.00	** 109.61
Trend	** 1.44	0.33	** 1.80	** 2.39	** 2.16
RainNvMy	1.78	* 3.40	** 4.21	-0.07	* 1.39
PlntMay	-3.58	1.06	-0.98	-0.25	-0.70
TempMay	0.40	1.56	** 3.48	-1.51	** 2.79
TempJun	3.94	1.92	** -4.03	0.79	0.96
HotJun	-2.01	-1.06	0.15	1.30	-1.97
RainJun	* 5.00	0.29	-0.29	1.27	-0.66
TempJly	-3.78	-2.42	-2.67	1.14	** -5.93
RainJly	** 17.59	** 6.85	** 9.64	2.41	** 3.75
HotDryJlym	1.40	4.35	2.00	** -8.69	* 2.08
WetJlym	-7.57	4.37	-3.94	-0.25	-2.42
D##@	D13a	D14a	D15a	D16a	D17a
	3.79	1.98	** -22.01	** 23.94	** -12.24
	D13c	D14b	D15b	D16b	D17b
	-2.08	-2.84	** -15.10	** 40.57	-3.94
	D13d	D14c	D15c	D16c	D17c
	-7.28	-8.12	5.75	** 22.00	** -7.66
	D13e	D14d	D15d	D16d	D17d
	** -14.51	7.41	* -7.99	** 24.79	-0.45
		D14e	D15e	D16e	D17e
		0.31	** -17.07	** 32.22	-2.13
				D16f	D17f
				** 17.55	1.47
				D16g	D17g
				** 17.46	5.15
					D17i
					-0.86
Constant = CRD#	13b	14f	15f	16h	17h
R ²	0.67	0.46	0.80	0.71	0.87
Adjusted R ²	0.60	0.36	0.76	0.67	0.85
Standard Error	15.69	13.65	9.16	12.88	6.54

Table 6. September 1 Crop-Weather Models by Region for 1974-1991

Variable	Region					
	1	2	3	4	5	6
Constant	** 85.33	** 93.91	** 103.15	** 116.50	** 70.02	** 107.27
Trend	** 1.56	** 1.72	** 1.27	* 0.67	** 2.65	0.73
RainNvMy	-1.93	-0.16	* -3.66	-0.33	-0.24	0.52
PlntMay	-1.63	0.94	1.65	1.16	* -4.27	-1.59
TempMay	2.37	0.59	-2.95	3.14	1.97	5.91
TempJun	* -3.37	** -3.85	* -4.94	* 4.22	** -4.63	-0.17
HotJun	-1.71	3.13	3.61	3.40	2.71	4.99
RainJun	1.89	** 4.04	1.87	** 3.62	** 3.87	** 6.66
TempEJly	** -5.70	-2.90	-2.04	* -1.20	* -2.57	* -5.94
RainEJly	** 3.95	** 4.07	** 8.38	2.07	-0.69	1.24
TempMJly	* -3.42	** -6.45	* -4.01	** -8.06	-1.24	-3.37
RainMJly	** 7.86	** 6.64	** 6.41	* 7.30	* 4.26	3.85
TempLJly	-1.68	-0.13	3.26	-0.05	-1.70	-1.22
RainLJly	2.26	** 6.57	6.05	** 8.62	** 4.29	* 6.84
HotDryJly	* 15.89	-1.81	-12.41	6.94	6.45	1.62
WetJly	** -11.79	** -11.79	** -16.93	** -17.64	* -8.95	-4.37
TempEAgst	1.14	0.07	0.69	-2.19	-2.06	-1.68
RainEAgst	** 4.34	* 3.08	1.91	-1.08	1.43	-3.16
TempLAgst	* -2.93	** -4.82	-3.43	** -11.73	-2.36	** -7.76
RainLAgst	* 2.83	0.48	* 4.32	* 4.40	1.12	2.59
WetAgst	* -6.67	-3.06	-4.73	-1.20	0.84	0.16
D##@	D1a	D2b	D3b	D4b	D5a	D6a
	1.75	-0.31	** -12.38	* -6.65	* -5.25	-2.36
	D1b	D2c	D3c	D4c	D5b	D6c
	** 9.06	-4.24	** -9.71	-2.59	* 5.39	-0.04
	D1c	D2d		D4d	D5c	D6d
	5.17	4.26		** -9.25	* -4.85	* -9.82
	D1d	D2e		D4e	D5d	D6e
	* 5.67	0.78		* -6.50	-2.43	-2.32
	D1e	D2f		D4f		
	3.59	0.84		-3.67		
		D2g				
		1.00				
		D2h				
		1.69				
Constant = CRD#	1f	2c	3a	4a	5e	6b
R ²	0.77	0.83	0.95	0.87	0.87	0.76
Adjusted R ²	0.70	0.79	0.91	0.83	0.82	0.68
Standard Error	7.81	8.57	5.86	9.33	7.13	12.36

Table 6. (continued)

Variable	Region					
	7	8	9	10	11	12
Constant	** 93.12	** 81.48	** 70.85	** 82.39	** 81.44	** 101.73
Trend	** 2.51	** 2.10	** 2.78	** 2.13	** 3.02	* 1.13
RainNvMy	** -4.44	* -3.04	** -4.00	-1.63	-2.92	0.53
PlntMay	* -3.38	** -4.54	** -5.25	** -4.63	-1.90	1.00
TempMay	-0.61	** 5.24	0.81	** 4.60	-5.24	3.09
TempJun	-2.40	2.92	1.23	** -4.80	-0.40	2.59
HotJun	-5.22	** -13.47	** -8.36	5.87	-9.34	-9.13
RainJun	0.81	0.95	-0.23	* 4.13	-3.46	** 6.08
TempEJly	** -5.03	2.34	** -4.53	** -5.99	-6.95	* -3.37
RainEJly	1.78	** 8.00	* 2.49	-1.16	2.86	1.37
TempMJly	0.25	** -3.85	** 3.58	-0.79	-1.79	** -7.74
RainMJly	* 3.88	3.88	2.43	** 8.28	-0.65	* 5.67
TempLJly	0.83	* -5.34	0.77	-1.41	2.44	* -3.54
RainLJly	1.96	* 3.03	2.32	3.07	-1.00	** 5.57
HotDryJly	* -10.91	* -8.32	7.78	13.75	-11.00	8.92
WetJly	-5.81	-1.02	-2.68	* -11.05	4.42	* -9.55
TempEAgst	-2.71	3.67	* -2.39	** -4.47	-1.69	0.88
RainEAgst	2.54	0.78	-0.47	2.92	3.25	* 5.05
TempLAgst	-3.08	** -4.80	** -4.94	-2.41	-4.28	** -7.35
RainLAgst	** 6.34	3.15	2.51	** 5.47	7.10	* 4.81
WetAgst	-7.59	-4.27	-2.38	-4.57	-12.31	** -16.35
D##@	D7a	D8a	D9a	D10a	D11b	D12a
	3.92	** -29.85	** -10.88	** 6.06	-2.53	** -14.44
	D7b	D8b	D9b	D10b		D12b
	0.83	** -12.95	* -7.55	* 4.56		** -24.44
	D7d	D8d	D9c			D12c
	* 7.30	-3.28	* -7.59			** -17.11
	D7e		D9d			D12d
	4.70		-5.46			** -15.80
	D7f		D9e			
	2.35		3.40			
			D9f			
			3.78			
Constant = CRD#	7c	8c	9g	10c	11a	12e
R ²	0.81	0.95	0.80	0.93	0.92	0.87
Adjusted R ²	0.76	0.92	0.75	0.88	0.81	0.82
Standard Error	9.74	7.04	9.06	6.53	9.75	9.41

Table 6. (continued)

Region					
Variable	13	14	15	16	17
Constant	** 60.08	** 38.61	** 48.78	** 73.48	** 107.81
Trend	** 1.77	0.52	** 1.98	** 2.54	** 2.29
RainNvMy	1.89	* 3.30	** 4.13	-0.04	** 1.71
PlntMay	* -5.54	0.46	-1.84	-0.15	-1.03
TempMay	-2.57	-0.54	-0.57	-1.82	0.35
TempJun	3.04	1.63	** -3.79	0.36	0.80
HotJun	4.20	4.06	3.77	1.67	2.60
RainJun	3.26	-0.18	1.15	0.69	-0.02
TempJly	-3.96	-2.92	-0.44	0.52	** -3.57
RainJly	* 10.67	1.70	** 6.99	-1.06	1.88
HotDryJlym	-0.50	5.71	-1.40	** -6.50	0.16
WetJlym	-1.97	7.31	-4.72	2.26	-0.93
TempAgst	* -6.11	* -6.12	** -4.08	* -4.84	** -4.67
RainAgst	3.52	-0.30	** 4.76	-3.56	** -2.81
WetAgstm	0.39	2.56	-1.84	4.63	1.57
D##@	D13a	D14a	D15a	D16a	D17a
	3.79	2.01	** -22.09	** 24.53	** -12.57
	D13c	D14b	D15b	D16b	D17b
	-1.89	-3.25	** -15.06	** 41.18	* -4.07
	D13d	D14c	D15c	D16c	D17c
	-7.54	-7.89	* 5.47	** 21.98	** -7.79
	D13e	D14d	D15d	D16d	D17d
	** 14.95	7.23	** -8.33	** 25.11	-0.52
		D14e	D15e	D16e	D17e
		0.29	** -17.45	** 32.51	-2.35
				D16f	D17f
				** 17.83	0.89
				D16g	D17g
				** 17.52	* 4.83
					D17i
					-1.41
Constant = CRD#	13b	14f	15f	16h	17h
R ²	0.72	0.51	0.86	0.73	0.90
Adjusted R ²	0.65	0.41	0.83	0.68	0.88
Standard Error	14.55	13.19	7.66	12.67	5.89

Table 7. October 1 Crop-Weather Models by Region for 1974-1991

Variable	Region					
	1	2	3	4	5	6
Constant	** 89.53	** 95.93	** 106.91	** 115.75	** 70.03	** 110.65
Trend	** 1.20	** 1.48	0.74	0.68	** 2.66	0.55
RainNvMy	0.85	0.55	-1.32	-0.31	-0.46	1.11
PlntMay	2.92	1.96	2.01	0.90	-3.90	-2.39
TempMay	-0.67	-0.25	-4.83	4.10	1.74	* 7.24
TempJun	-0.17	** -3.72	* -5.38	2.92	** -4.71	-2.19
HotJun	-3.57	4.59	2.43	2.07	2.76	6.17
RainJun	1.89	** 4.04	1.82	** 3.71	** 3.99	** 8.54
TempEJly	* -3.26	-1.94	-3.24	-2.22	-2.54	** -8.10
RainEJly	* 2.58	** 3.20	* 8.71	1.72	-0.59	-2.08
TempMJly	** -4.69	** -8.23	-5.08	** -9.74	-1.05	-5.32
RainMJly	** 7.17	** 6.12	** 6.76	** 6.14	* 4.22	2.90
TempLJly	* -3.23	0.06	2.44	-0.53	-1.93	1.86
RainLJly	1.35	** 6.12	0.89	** 8.86	** 4.44	* 7.41
HotDryJly	10.87	-0.97	* -17.85	7.61	6.90	-4.34
WetJly	** -11.79	** -11.58	-14.29	** -15.62	* -9.23	-1.62
TempEAgst	* 2.88	1.33	2.45	-1.97	-1.98	0.64
RainEAgst	** 4.80	2.58	0.64	-0.89	1.30	-1.69
TempLAgst	** -4.69	** -5.45	* -5.14	** -10.58	-2.06	-5.26
RainLAgst	2.49	0.19	3.17	* 3.80	1.25	3.08
WetAgst	* -6.24	-2.54	0.28	-1.09	0.89	-4.39
TempSep	** 6.29	* 2.66	3.73	1.51	-0.11	-0.28
RainSep	0.97	1.14	-3.00	* 3.05	-0.49	** 7.77
HotDrySep	-2.15	0.37	-0.60	0.71	0.76	0.62
D##@	D1a	D2b	D3b	D4b	D5a	D6a
	1.67	-0.49	** -12.77	* -6.34	* -5.36	-2.49
	D1b	D2c	D3c	D4c	D5b	D6c
	** 8.99	-4.37	** -9.53	-2.52	* 5.26	-0.80
	D1c	D2d		D4d	D5c	D6d
	* 5.08	4.05		** -9.20	* -4.94	* -10.24
	D1d	D2e		D4e	D5d	D6e
	* 5.84	0.71		* -6.54	-2.46	-2.59
	D1e	D2f		D4f		
	3.61	0.58		-3.52		
		D2g				
		0.67				
		D2h				
		1.58				
Constant = CRD#	1f	2c	3a	4a	5e	6b
R ²	0.82	0.84	0.95	0.88	0.87	0.83
Adjusted R ²	0.75	0.79	0.91	0.83	0.82	0.75
Standard Error	7.04	8.44	5.61	9.13	7.28	10.90

Table 7. (continued)

Variable	Region					
	7	8	9	10	11	12
Constant	** 90.11	** 81.42	** 74.48	** 81.44	** 88.95	** 101.53
Trend	** 2.91	** 2.19	** 2.80	** 2.26	** 2.67	** 1.10
RainNvMy	-1.65	* -2.95	** -3.65	-2.35	0.58	0.44
PlntMay	-0.98	** -4.26	** -5.44	-3.80	2.39	0.72
TempMay	-1.65	* 4.30	1.40	** 5.12	-5.15	3.19
TempJun	-2.46	3.04	1.03	** -4.75	-1.29	2.15
HotJun	-5.73	** -13.34	** -8.32	5.17	-2.49	-8.88
RainJun	2.47	1.67	0.10	* 4.15	-0.14	** 6.12
TempEJly	** -4.55	2.76	** -4.57	** -7.24	-1.82	-3.30
RainEJly	1.63	** 7.73	2.39	-0.59	2.99	1.37
TempMJly	-0.99	** -3.95	** 3.86	0.45	* -9.65	** -8.33
RainMJly	2.53	* 3.25	2.63	** 8.73	2.39	* 4.97
TempLJly	0.36	* -5.64	0.75	-1.07	-0.74	-3.60
RainLJly	-1.17	2.95	2.26	3.29	3.52	* 4.78
HotDryJly	* -12.34	-9.40	7.43	10.64	-5.43	9.13
WetJly	-0.76	-1.11	-2.51	* -13.05	-4.21	-6.80
TempEAgst	* -4.30	3.89	* -2.27	* -4.79	-3.46	0.50
RainEAgst	3.54	0.92	-0.18	1.22	6.62	* 5.00
TempLAgst	* -4.26	** -6.09	** -4.88	-2.47	-4.85	* -7.19
RainLAgst	** 7.68	2.41	2.77	* 4.88	* 7.99	** 4.97
WetAgst	* -9.44	-4.56	-2.80	-1.96	* -17.10	** -16.15
TempSep	4.53	1.89	0.63	-2.02	6.62	1.29
RainSep	-2.97	0.11	-1.13	-0.22	-6.81	0.18
HotDrySep	* -15.01	-5.26	-0.63	5.69	* -30.05	-3.73
D##@	D7a	D8a	D9a	D10a	D11b	D12a
	3.90	** -29.33	** -14.61	* 4.92	-0.92	** -14.77
	D7b	D8b	D9b	D10b		D12b
	1.44	** -13.01	** -11.33	3.92		** -24.35
	D7d	D8d	D9c			D12c
	* 6.70	-3.32	** -11.30			** -17.03
	D7e		D9d			D12d
	4.83		** -9.17			** -16.15
	D7f		D9e			
	2.60		-0.31			
			D9f			
			-3.74			
Constant = CRD#	7c	8c	9g	10c	11a	12e
R ²	0.83	0.95	0.80	0.93	0.95	0.87
Adjusted R ²	0.77	0.92	0.75	0.87	0.85	0.81
Standard Error	9.50	6.99	9.15	6.63	8.69	9.57

Table 7. (continued)

Variable	Region				
	13	14	15	16	17
Constant	** 63.93	** 40.05	** 50.52	** 72.48	** 108.64
Trend	** 1.57	0.47	** 1.80	** 2.61	** 2.25
RainNvMy	2.20	* 3.87	** 4.08	0.03	** 1.57
PlntMay	** -5.50	-0.88	* -2.15	-1.12	-0.94
TempMay	0.88	1.56	-0.87	-1.92	0.04
TempJun	0.63	0.90	* -2.86	1.04	1.38
HotJun	0.92	4.79	2.20	1.69	1.55
RainJun	3.58	0.31	1.25	0.50	-0.20
TempJly	** -7.86	* -5.03	-1.02	0.02	** -3.94
RainJly	* 9.87	1.28	** 6.02	-1.07	2.15
HotDryJlym	2.80	* 8.19	-1.27	* -6.14	0.25
WetJlym	-4.34	5.85	-3.74	2.92	-1.03
TempAgst	** -8.84	* -7.05	* -3.44	-3.76	** -4.05
RainAgst	4.26	-0.18	** 5.60	-3.38	* -2.21
WetAgstm	-4.02	-0.16	-2.74	4.61	1.13
TempSep	** 8.95	3.32	-0.29	-1.42	-0.89
RainSep	1.72	* 3.79	* 2.09	2.22	0.03
HotDrySep	-6.59	-0.42	0.25	2.22	-1.22
D##@	D13a	D14a	D15a	D16a	D17a
	4.53	2.02	** -21.91	** 24.20	** -12.58
	D13c	D14b	D15b	D16b	D17b
	-2.42	-3.42	** -15.02	** 40.90	* -3.95
	D13d	D14c	D15c	D16c	D17c
	-7.27	-8.20	* 5.60	** 21.58	** -7.84
	D13e	D14d	D15d	D16d	D17d
	** -15.28	6.98	** -8.29	** 24.99	-0.59
		D14e	D15e	D16e	D17e
		0.29	** -17.32	** 32.27	-2.24
				D16f	D17f
				** 17.71	0.98
				D16g	D17g
				** 17.38	* 4.90
					D17i
					-1.36
Constant = CRD#	13b	14f	15f	16h	17h
R ²	0.79	0.56	0.87	0.73	0.90
Adjusted R ²	0.72	0.44	0.84	0.68	0.88
Standard Error	13.12	12.78	7.60	12.66	5.87

Table 8. Summary of Significant Rainfall Variables for Crop-Weather Models by Region*

Region												
Variable	1	2	3	4	5	6	7	8	9	10	11	12
RainNvMy	-A		-JAS				-JAS	-ASO	-JASO	-J		
RainJun	+J	+JASO	+J	+ASO	+JASO	+JASO				+ASO	-J	+JASO
RainEJly	+ASO	+ASO	+ASO	+A				+ASO	+AS	-A	+A	+A
RainMJly	+ASO	+ASO	+ASO	+ASO	+ASO		+S	+AO		+ASO	+A	+ASO
RainLJly		+ASO	+A	+ASO	+ASO	+ASO		+AS				+ASO
RainEAgst	+SO	+S										+SO
RainLAgst	+S		+S	+SO			+SO			+SO	+O	+SO
RainSep				+O		+O						

Region					
Variable	13	14	15	16	17
RainNvMy		+JASO	+JASO		+ASO
RainJun	+A				
RainJly	+ASO	+A	+ASO		+A
RainAgst			+SO		-SO
RainSep		+O	+O		

* : Variables significant at the 5% level. Coefficient signs are indicated.

J = July 1 model, A = August 1 model, S = September 1 model, O = October 1 model

Rainfall during July has a significant positive yield effect in most areas of the Corn Belt. There is some variation among eastern Corn Belt regions regarding whether early July (RainEJly) and late July (RainLJly) rainfall has a positive yield impact or not, and whether the positive impacts are significant across all the monthly crop-weather models. Early July rainfall has a positive yield impact in parts of Ohio and Indiana (regions 1, 2, and 3) and of Minnesota and Wisconsin (regions 8 and 9). Mid-July rainfall positively affects yields in Iowa and southern Minnesota in the September 1 model, and has a consistent positive effect on yields throughout the Corn Belt, the only exception being in regions 6 (northern Illinois and southeast/south central Iowa) and 9 (northern two thirds of Wisconsin). Late July rainfall (RainLJly) has a significant positive yield impact in eastern Corn Belt regions (2, 3, 4, 5, and 6), parts of Minnesota (region 8) and the southern Corn Belt (region 12). In general the positive effect of July rainfall is not as consistently significant in the middle Corn Belt region as in the eastern Corn Belt. However, as reported in Table 10, in many eastern Corn Belt regions (1, 2, 3, 4, and 5) as well as in other parts of Wisconsin and the southern Corn Belt (regions 10 and 12) extremely wet July conditions have a negative impact on corn yields. In these areas, increases in July rainfall have a positive yield impact up to a point, after which yields either no longer positively respond to the same degree to additional rainfall or actually decline. An increase in July monthly rainfall (RainJly) in the western Corn Belt has a positive impact on nonirrigated corn yields in the western two-thirds of Nebraska and Kansas (regions 13, 14 and 15).

August rainfall increases yields in a number of eastern and middle Corn Belt areas. Early August rainfall (RainEAgst) increases yields in Ohio and parts of Indiana, as well as in Missouri, southern Illinois and south central Iowa (regions 1, 2

and 12). Late August rainfall (RainLAgst) increases yields in parts of Ohio, Indiana, Illinois, Iowa, Missouri, southern Minnesota and southern Wisconsin (regions 1, 3, 4, 7, 10, 11 and 12). However, as reported in Table 10, in some areas of Ohio, Iowa, Missouri and southern Illinois (regions 1, 7, 11 and 12) extremely wet August conditions bring about a negative yield response. Yields in these areas either do not continue to show the same positive response to rainfall received after reaching a threshold level or actually decline. In the western Corn Belt, August monthly rainfall (RainAgst) is positively related to yields in the northeast and western two-thirds of Nebraska for nonirrigated production (region 15), but is negatively related to yields in Nebraska and northwest Kansas irrigated corn production (region 17). September monthly rainfall (RainSep) has a positive yield effect in parts of Illinois, Indiana and eastern Iowa (regions 4 and 6), as well as on nonirrigated yields in the western two-thirds of both Kansas and Nebraska, and in northeast Nebraska (regions 14 and 15).

These results are consistent with Thompson's for the Illinois, Indiana, Iowa, Missouri and Ohio for 1930 through 1983. In Thompson's quadratic model ($Y = a + b_i D_i \text{Trend} + cX + dX^2$, Y = yield, X = weather variables) the linear effect of preseason precipitation on corn yields (represented by the c coefficient) is negative. In these crop-weather models, where RainNvMy is significant for these same eastern and middle Corn Belt states or regions, it also has a negative impact on yields. The yield effect of both July and August monthly rainfall was positive but decreasing at extreme levels in Thompson's results and in a number of these crop-weather models as well. Thompson's model is extended in this research by considering intramonth rainfall data (i.e., the variables RainEJly, RainMJly, RainLJly, RainEAgst and RainLAgst) in the middle and eastern Corn Belt regions instead of the monthly rainfall (i.e.

RainJly and RainAgst). The inclusion of intramonth rainfall variables in crop-weather models allows for measurement of the temporal distribution effects of rainfall throughout the July and August time period.

Table 9 gives a summary of significant temperature variables for the crop-weather models by region. The impacts of extreme temperature related aridity index variables are included in Table 10. In general, warmer than average temperatures during June have a negative impact on corn yields in the Corn Belt. In some areas of the upper mid-western Corn Belt (parts of Iowa and Wisconsin, all of Minnesota) extremely hot June temperatures have a further negative yield impact. In general, corn yields are negatively affected by high temperatures during the critical corn development months of July and August. There are some exceptions to this in the extreme northern and eastern Corn Belt regions.

Looking at the effects of specific temperature variables, May average temperatures (TempMay) had a positive yield impact in the upper mid-western Corn Belt regions. Central, eastern and northern Iowa, Minnesota, northern and east central Illinois, and Wisconsin show the most consistent response to warmer than normal May temperatures throughout the four monthly models (regions 6, 8, 9 and 10). Higher than normal June average temperatures (TempJun) generally have a negative yield impact, especially in the eastern Corn Belt, Michigan, southern Wisconsin and for nonirrigated production in the western two-thirds of Nebraska (regions 1, 2, 3, 5 and 10). The only exception is in the September 1 model for the central parts of Illinois and Indiana (region 4) in which a positive response to higher June temperatures occurs.

In almost all middle and eastern Corn Belt regions, warmer than normal early July temperatures (TempEJly) have a negative impact on yields, with the most

Table 9. Summary of Significant Temperature Variables for Crop-Weather Models by Region*

Region												
Variable	1	2	3	4	5	6	7	8	9	10	11	12
TempMay	+A	+A			+A	+AO	+JA	+JASO	+JAO	+JAS		A
TempJun	-AS	-ASO	-ASO	+S	-JASO		-A	-J		-JASO		
TempEJly	-ASO	-A	-A	-AS	-AS	-ASO	-ASO		-ASO	-ASO	-A	-AS
TempMJly	-ASO	-ASO	-S	-ASO	-A			-ASO	+ASO		-O	-ASO
TempLJly	-AO	-A						-ASO				-S
TempEAgst	+O						-O		-SO	-SO		
TempLAgst	-SO	-SO	-O	-SO		-S	-O	-SO	-SO			-SO
TempSep	+O	+O										

Region					
Variable	13	14	15	16	17
TempMay			+A		+A
TempJun			-ASO		
TempJly	-O	-O			-ASO
TempAgst	-SO	-SO	-SO	-S	-SO
TempSep	+O				

* : Variables significant at the 5% level. Coefficient signs are indicated.

J = July 1 model, A = August 1 model, S = September 1 model, O = October 1 model

consistent effect throughout the models in Ohio, Michigan, central Indiana, Illinois, Iowa/southern Minnesota, and Wisconsin (regions 1, 4, 5, 6, 7, 9, 10 and 12). Higher middle July temperatures (TempMJly) have a negative yield effect in the eastern Corn Belt regions of Ohio, Indiana, and central and southern Illinois (regions 1, 2, 3 and 4). Parts of Minnesota, Missouri and Iowa (regions 8, 9, 11 and 12) are also negatively effected by high mid-July temperatures. Conversely, in part of the northern Corn Belt (the northern two-thirds of Wisconsin and east central Minnesota - region 9), corn yields are positively effected by warmer than normal mid-July temperatures. Late July temperatures (TempLJly) are negatively related to yields in Ohio, in western and central Minnesota, and in the southern Corn Belt (regions 1, 8 and 12). In the western Corn Belt warmer than normal July monthly average temperatures (TempJly) have a negative yield impact on Kansas and eastern Nebraska nonirrigated corn production (regions 13 and 14) and on irrigated yields in Nebraska and northwest Kansas (region 17).

Early August temperatures (TempEAgst) are positively related to yields in parts of Ohio (region 1), but are negatively related to yields in Iowa/southern Minnesota, Wisconsin and in east central Minnesota (regions 7, 9 and 10). Late August temperatures (TempLAgst) are negatively related to yields in Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa (except for the southwest and west central parts) and Missouri (regions 1, 2, 3, 4, 6, 7, 8, 9 and 12). In the western Corn Belt, warmer than normal August monthly average temperatures (TempAgst) lead to yield decreases in all nonirrigated and irrigated regions (13 through 17). September average temperatures (TempSep) have a positive relation to yields in Ohio and parts of Indiana as well as in nonirrigated eastern Kansas and east central and southeast Nebraska (regions 1, 2 and 13).

These results are consistent with Thompson's findings. For the eastern and central Corn Belt region Thompson found that corn yields are negatively related to higher than normal temperatures in June, July and August. Just as for the rainfall variables, these models extend Thompson's work by accounting for intramonth temperature variables (TemPEJly, TempMJly, TempLJly, TemPEAgst and TempLAgst) instead of only monthly variables (TempJly and TempAgst). As was true for the intramonthly rainfall variables, by including intramonth temperature variables in crop-weather models the temporal distribution effects throughout the July and August time period of temperature on corn yields can be more accurately measured.

Table 10 gives a summary of significant non-weather and aridity index variables measuring the yield impact of weather extremes for the crop-weather models by region. The yield trend is positive and significant in all of the monthly models for most of the regions, with an October 1 model average across all regions of plus 1.76 bushels per year, ranging from 0.68 to 2.91 bushels across the regions. The exceptions are for the yield trends in the October 1 crop-weather models for parts of Indiana, Illinois and Iowa (regions 3, 4, and 6) which are not significant. A major exception to the pattern of significant yield trends is found for nonirrigated production in the western two-thirds of Kansas (region 14), where the yield trend is not significant for any of the monthly models.

A higher than average percentage of the corn crop planted by mid-May (PlntMay) has a negative impact on corn yields in central and northern regions of the Corn Belt such as Michigan, the Iowa/southern Minnesota region, the remainder of Minnesota and Wisconsin (regions 5, 7, 8, 9 and 10). Yields in some western Corn Belt nonirrigated areas (eastern Kansas and Nebraska, regions 13 and 15) are also negatively affected by higher than normal mid-May corn plantings. This could be

Table 10. Summary of Significant Non-Weather and Aridity Index Variables for Crop-Weather Models by Region*

Region												
Variable	1	2	3	4	5	6	7	8	9	10	11	12
Constant	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO
Trend	+JASO	+JASO	+JAS	+JAS	+JASO	+JA	+JASO	+JASO	+JASO	+JASO	+JASO	+JASO
PlntMay					-JAS	-J	-JAS	-JASO	-JASO	-JAS	-J	
HotJun							-JA	-JASO	-JASO	+A	-A	
HotDryJly	+AS		-AO				-ASO	-AS				
WetJly	-ASO	-ASO	-AS	-ASO	-ASO					-ASO		-S
WetAgst	-SO						-O				-O	-SO
HotDrySep							-O				-O	

Region					
Variable	13	14	15	16	17
Constant	+JASO	+JASO	+JASO	+JASO	+JASO
Trend	+JASO		+JASO	+JASO	+JASO
PlntMay	-SO		-JO		-J
HotJun					
HotDryJlym		+O		-ASO	+A
WetJlym					
WetAgstm					
HotDrySep					

* : Variables significant at the 5% level. Coefficient signs are indicated.

J = July 1 model, A = August 1 model, S = September 1 model, O = October 1 model

due to the negative yield impact of drier than normal preseason soil moisture conditions, which in these regions would be positively correlated with a higher than normal percentage of corn planted by mid-May .

Extremely hot temperatures during June (Hot_{Jun}) have a negative yield impact in the upper mid-west, including parts of Iowa, Minnesota and Wisconsin (regions 7, 8 and 9). In contrast, hot June temperatures have a positive impact on southern Wisconsin corn yields. When combined with the significant negative yield effect of June temperatures (Temp_{Jun}) in these regions, these results indicate that up to a certain temperature level corn yields are reduced by higher temperatures. However, after reaching that temperature threshold level, yields decline at a slower rate as June temperatures move incrementally higher.

The combination of hot and dry conditions in middle and late July ($\text{HotDry}_{\text{Jly}}$) have a negative impact on corn yields in sections of Indiana, Iowa and Minnesota (regions 3, 7 and 8) and a positive yield impact in parts of Ohio (region 1). In regions 1, 3 and 8 (sections of Indiana, Minnesota and Ohio) the related July temperature and rainfall variables all have the expected significant negative and positive yield effects, respectively. The hot and dry aridity index effects in these regions represent an added yield impact from the simultaneous combination of hot and dry conditions, which is negative in southern Indiana and Minnesota (regions 3 and 8) and positive in Ohio (region 1). Conversely, in Iowa/southern Minnesota (region 7) the related temperature variables alone had no negative yield effect, while the rainfall variable for mid-August had a significant positive effect in the September 1 model. These results indicate that corn yields are generally not significantly affected by variation in weather conditions in this region, especially with respect to the effect of temperature variation on corn yields. However, the

combination of high temperatures and low rainfall during July in the Iowa/southern Minnesota area does have a significant negative corn yield impact. In contrast, hot and dry conditions for the month of July (HotDryJlym) have a positive yield impact on nonirrigated corn production in the western two-thirds of Kansas (region 14) for the October 1 model. In this same region corn yields are negatively related to July temperatures. Therefore, when hot and dry July conditions occur, the negative yield effect from high temperatures alone is offset by a positive yield impact of combined hot and dry conditions. This outcome is counter-intuitive, and may be a spurious result. Also in the western Corn Belt, hot and dry July conditions have a negative yield impact on irrigated corn production in Kansas (region 16). In this region neither July rainfall or temperatures alone have a significant yield impact. This indicates that only when much higher than average temperatures and much lower than average rainfall conditions occur together in this irrigated corn production region do these factors have a significant negative impact on corn yields.

Extremely wet conditions in July (WetJly) have a negative yield impact on eastern and southern Corn Belt areas, southern Wisconsin, and south central Iowa (regions 1, 2, 3, 4, 5 and 10). These same areas are positively affected by July rainfall. Therefore, in these regions July rainfall has a positive yield impact, but that positive yield impact is then offset either wholly or in part by excessively high July rainfall amounts. Yields in the western Corn Belt are not significantly effected by excessively wet July conditions (WetJlym), probably because of low relative humidity and average annual rainfall amounts in these regions.

Wet August conditions (WetAgst) have a negative impact on yields in parts of Ohio, Iowa, Minnesota, Missouri and southern Illinois (regions 1, 7, 11 and 12). In these same regions August rainfall has an otherwise positive yield impact.

Therefore, just as in the case of excessive July rainfall, yields are positively impacted by rainfall in August up to a point, after which the positive yield impact from more rainfall is offset either wholly or in part. Western Corn Belt yields are not significantly affected by wet August conditions (WetAgstm).

Hot and dry conditions in September (HotDrySep) have a negative effect on yields in Iowa (except for the southeast and east central districts) and in southern Minnesota (regions 7 and 11). In these regions neither temperature or rainfall alone in September have significant yield impacts. This indicates that higher than average temperatures and lower than average rainfall only significantly impact corn yields when they occur simultaneously.

Whereas Thompson represented declining yield responsiveness to weather conditions using quadratic terms, this model represents them using aridity indices. Thompson's model is extended by considering the yield impact of simultaneous combinations of extreme temperature and rainfall conditions. These results are generally consistent with Thompson's yield effects from quadratic weather variables, which indicated a declining yield response to increases in all monthly temperature and rainfall variables. The aridity indices used here (HotJun, HotDryJly, HotDryJlym, WetJly, WetJlym, WetAgst, WetAgstm and HotDrySep) perform a function similar to the quadratic terms in Thompson's model, that of adjusting yields for extreme weather conditions which occur either alone (in the cases of HotJun, WetJly, WetJlym, WetAgst, and WetAgstm) or in combination with other extreme weather conditions during the same time period (as with HotDryJly, HotDryJlym and HotDrySep). For the large majority of aridity index variables throughout the various regions and monthly models, the extreme conditions represented by these variables have a negative yield impact, which is consistent

with what Thompson found. Additionally, the use of combination aridity indices in these crop-weather models add to the understanding of how simultaneous combinations of extreme weather conditions impact corn yields in different corn production regions.

Figure 3 illustrates changes in the standard error of crop-weather model yield estimates that occur for the successive monthly models in the crop production regions. Across the 17 regional models there is an average 4.35 bushel decrease in standard error between July 1 and August 1. The standard error average change decreases to 1.11 bushel between the August 1 and September 1 estimates, and to 0.35 between the September 1 and October 1 estimates. The smallest decrease in standard errors between July 1 and August 1 occur in region 5 (central and southern Michigan). Some of the largest decreases between the July 1 and August 1 models occur in Illinois, Indiana, eastern portions of Iowa, Ohio (i.e., regions 1, 2, 3, 4, and 6) and in eastern Kansas - southeastern Nebraska, (both nonirrigated) and Missouri (regions 12 and 13). Between August 1 and September 1 the largest decreases in standard error occur in the mid-Illinois/Indiana area, southern Wisconsin and the southern Illinois/south central Iowa/Missouri area (regions 4, 10 and 12). Small decreases in standard error occur in most regions between the September 1 and October 1 models, with the largest decreases in northern Illinois - east and southeast Iowa, in southwest and west central Iowa, and the eastern Kansas - east central and southeast Nebraska area (regions 6, 11 and 13).

Figure 4 shows R^2 values for the successive monthly models in each of the 17 corn production regions. The average increase in R^2 across regions between the July 1 and the August 1 models is 29 percent. There is a 5 percent average increase in R^2 between the August 1 and September 1 model estimates, and 2 percent average

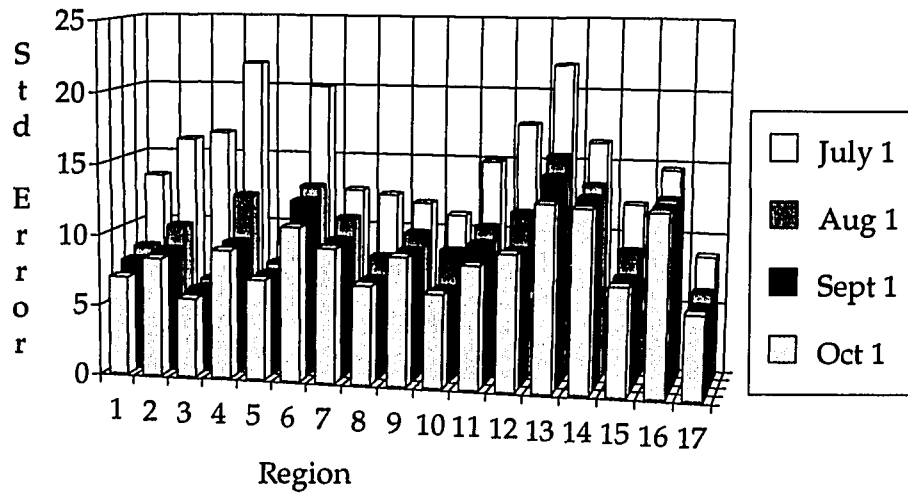


Figure 3. Standard Error of Monthly Models by Region

increase between the September 1 and October 1 estimates across all the models. Although there is some similarity between the group of regions that have the largest standard errors and those that have the lowest R^2 values in July 1 model estimation, there is not total consistency. For example, region 1 (east, central and southern Ohio) has a smaller July 1 model standard error than regions 2 and 3, but has a lower July 1 R^2 value. Region 13 has one of the two highest July 1 model standard errors but only a moderately low July 1 R^2 value. The low R^2 values for region 14 indicate that the level and variation in nonirrigated corn yields in the western two thirds of Kansas was not well explained by that region's crop-weather model.

One of the purposes of this study is to extend Thompson's monthly crop-weather model by considering intramonth weather data during critical periods of corn development. By using intramonthly instead of monthly weather data during

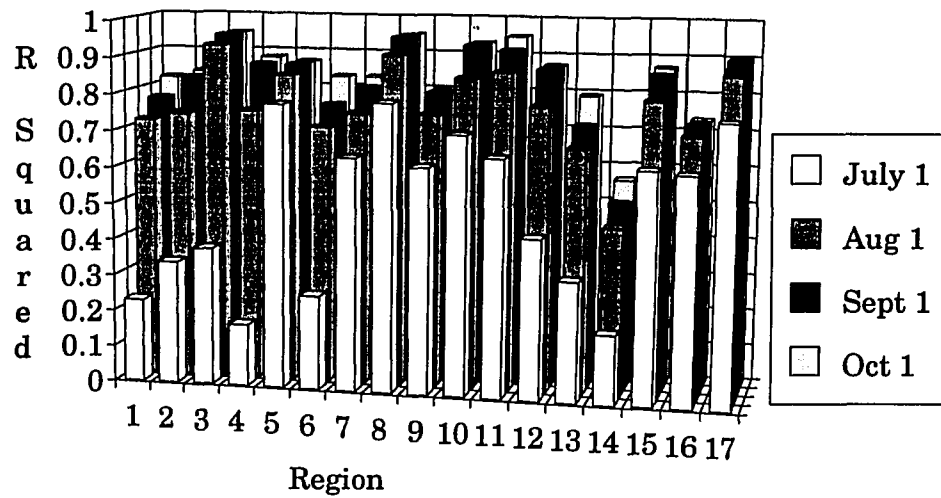


Figure 4. R-Squared Values for Monthly Models by Region

July and August in the crop-weather models for the twelve eastern Corn Belt regions in this study, the average R^2 for the August 1, September 1 and October 1 models are increased by 3%, 4% and 3%, respectively. The corresponding average reductions in model standard errors caused by using intramonthly versus monthly weather data are 0.43 , 0.67 and 0.61 bushels per acre for the August 1, September 1 and October 1 models, respectively. The model by model comparison of estimation results using intramonth versus monthly explanatory variables is not reported here.

These results for specific crop-weather model rainfall, temperature and aridity index variables as well as the comparative standard error and R^2 results have implications for forecasters of U.S. corn yield and production. They reaffirm the general ideas that favorable rainfall and temperature conditions during planting time and during July and August have critical impacts on corn yield. However,

they do indicate that attention should be given to potential yield damage from excessive pre-season rainfall in some middle and northern Corn Belt regions, from excessive June temperatures in the upper midwest, and from excessive rainfall in July and August in many areas of the eastern Corn Belt. These results also show that forecasters should be aware of the potential damage that can be caused from a combination of high temperatures and low rainfall during July and even September in some regions of the Corn Belt. The standard error and R^2 results indicate that most of the increase in model accuracy that will occur will take place between the July 1 and the August 1 crop-weather model estimates. After the initial gain in accuracy from July 1 to August 1, model standard errors and R^2 measures improve to a lesser degree between the August 1 to the September 1 models, and then only marginally between the September 1 and the October 1 model.

The standard errors of the crop-weather model estimates represented in Figure 3 play an important part in the forecast procedure to be used below. Because of the method by which unconditional forecast errors are derived (as explained in the following section), the standard error of forecast will always be at least slightly larger than the estimated standard error of the underlying crop-weather model. As a result, the monthly crop-weather model standard errors will be major determinants of the potential accuracy of any forecasts derived from these models, the possible increase in accuracy that successive monthly forecasts may be likely to have through time, and the shape of the forecast error distribution. A more complete discussion of the method used to calculate an unconditional forecast error is given below.

Deriving Yield and Production Forecasts

Crop reporting district level corn yield forecasts are obtained from the regional corn yield models using known weather data for the forecast period. Crop reporting district level corn production forecasts are derived by multiplying the unconditional yield forecast for each district by a district level estimate of harvested acres. Crop reporting district level harvested acreage is estimated during the growing season using a two step approach. First, a projection of state level harvested acreage is derived. The most current planted acreage estimate for the relevant state is multiplied by the most recent 5 year average of the percent harvested to planted acreage. Historic state level planted to harvested acreage relationships are used because only state level planted acreage projections are available prior to corn harvest. Second, crop reporting district level harvested acreage is calculated from the historic relation between state and crop reporting district level harvested acreage. In this procedure the level of harvested acreage for each crop reporting district is assumed to be known with certainty. Without this simplifying assumption another source of variability would have to be accounted for in the calculation of forecast uncertainty, adding to the complexity of the calculations while the gain in forecast accuracy would be questionable. Forecast corn production for a specific crop production district (i.e., district "i") is calculated as follows:

$$E[\text{PRODN}_i] = E[\text{HarvAcres}_i \times \text{Yld}_i] = \text{HarvAcres}_i \times E[\text{Yld}_i]$$

where,

$E[\text{PRODN}_i]$ = Forecast production for district i

HarvAcres_i = Estimate of harvested acreage for district i

$E[\text{Yld}_i]$ = Forecast Yield for district i

The crop-weather models include Corn Belt regions which produced on average 83% of the U.S. corn crop during 1989-1991. Aggregation of the crop-weather district production

forecasts into one overall Corn Belt production forecast and forecast variance for the July 1, August 1, September 1 and October 1 is carried out in the following manner.

$$\begin{aligned} E[\text{PRODN}_{\text{CB}}] &= \sum_i^{\text{\#CRDs}} E[\text{PRODN}_i] \\ &= \sum_i^{\text{\#CRDs}} \text{HarvAcres}_i \times E[\text{Yld}_i] \end{aligned}$$

where,

$E[\text{PRODN}_{\text{CB}}]$ = Forecast production for the Corn Belt

$E[\text{PRODN}_i]$ = Forecast production for district i

HarvAcres_i = Estimate of harvested acreage for district i

$E[\text{Yld}_i]$ = Forecast yield for district i

To derive a forecast of total U.S. corn production, corn yields and production must be forecast for the areas of the U.S. not included in the Corn Belt (i.e., in the 17 crop-weather model regions). Then the non-Corn Belt corn production forecast is aggregated together with the Corn Belt production forecast to obtain the forecast of total U.S. corn production.

The corn producing areas not included in the crop-weather model regions accounted for approximately 17% of U.S. corn production during the 1989-91 period. Because of a lack of weather data for these non-Corn Belt regions, non-Corn Belt yields ($Y_{\text{NonCornBelt}}$) are estimated as a function of Trend and Corn Belt average yields (Y_{CornBelt}). The results of non-Corn Belt model estimation for 1974-1991 are as follows (t-test values in parenthesis):

$$Y_{\text{NonCornBelt}} = 30.65 + 0.83 \cdot \text{Trend} + 0.42 \cdot Y_{\text{CornBelt}}$$

(3.56) (2.89) (4.49)

Number of Observations = 18 $R^2 = 0.82$

Standard Error = 5.16 Adjusted $R^2 = 0.79$

From this model, forecasts of non-Corn Belt yields are made using the Corn Belt yield forecasts (i.e., the 50% probability point on the cumulative probability distribution of Corn Belt corn yields) for July 1, August 1, September 1 and October 1. An estimate of non-Corn Belt harvested corn acreage is multiplied by the forecast non-Corn Belt yield to calculate the non-Corn Belt corn production forecast. Non-Corn Belt harvested corn acreage is estimated from the historic ratio between non-Corn Belt planted and harvested acres (5 year average percent harvested/planted acreage).

Aggregation of the non-Corn Belt forecast together with the Corn Belt forecast will be carried out in the following manner.

$$\begin{aligned} E[\text{PRODN}_{\text{US}}] &= \sum_i^{\text{\#CRDs+NonCB}} E[\text{PRODN}_i] \\ &= \sum_i^{\text{\#CRDs+NonCB}} \text{HarvAcres}_i \times E[\text{Yld}_i] \end{aligned}$$

where,

$E[\text{PRODN}_{\text{US}}]$ = Forecast production for the United States

$E[\text{PRODN}_i]$ = Forecast production for district i

HarvAcres_i = Estimate of harvested acreage for district i

$E[\text{Yld}_i]$ = Forecast Yield for district i

Calculating Yield and Production Forecast Errors

Unconditional forecasts

If a yield forecast is made using weather information that is known at the time of the forecast, it is an unconditional forecast. For unconditional forecasts from the crop-weather models estimated via ordinary least squares, the yield predictions are unbiased and the forecast errors are normally distributed around the forecast of average yield. The formulas

for calculating the unconditional forecast error for both the univariate and multivariate cases are given below (See Ladd, Morris and Cha, 1984; Kmenta, 1986; Ladd, Duncan, and Han, 1992; and Pindyck and Rubinfeld, 1991). Assuming that the crop-weather models can be represented in general form as $Y_t = x_t * b + e_t$ in the univariate case, and $Y_t = X_t' * B + e_t$ in the multivariate case, with standard OLS assumptions for both, the respective unconditional forecast error equations are as follows.

Univariate case:

$$s_f^2 = s^2 * \left[1 + 1/T + \{x_{T+1} - x^{\text{BAR}}\} / \sum \{x_t - x^{\text{BAR}}\}^2 \right]$$

Multivariate case:

$$s_f^2 = s^2 * \left[1 + X_k(X'X)^{-1}X_k' \right]$$

where,

s_f^2 = Forecast variance of the OLS model forecast

s^2 = Variance of the OLS model estimate

x = Univariate explanatory variable

x_{T+1} = Known univariate explanatory variable during the forecast period

x^{BAR} = Mean of univariate explanatory variable for estimation period

X = Multivariate explanatory variable matrix

X_k = Known vector of explanatory variables during the forecast period

T = Number of observations used for model estimation

b, B = Parameter estimates (univariate and multivariate, respectively)

e_t, e_t = Estimation errors (univariate and multivariate, respectively)

A key principle in unconditional forecasting is that the greater the difference between the value of a forecast period explanatory variable and the mean of that variable during the period of model estimation, the larger the forecast error is in relation to the standard error of

the estimated econometric model. For example, historically large rainfall amounts received during the summer of 1992 caused relatively large errors in preharvest 1992 corn yield forecasts in the regional crop-weather models. If the amount of summer time rainfall received during an out-of-sample forecast year is approximately equal to the historic average rainfall during the model estimation period, then the difference between the standard error of the model and the forecast error of the yield estimate will be very small. In this case, the difference between them would mainly depend on the number of observations used in model estimation. This principle holds true in both the univariate and multivariate cases.

Crop reporting district level yield and production forecast confidence intervals and probability distributions can be estimated using forecast yield, the forecast error (s_f) and t-distribution values. Because the forecast error is normally distributed with mean 0 and variance σ^2 , significance tests can be performed on y_0 , the forecast value of Y, by calculating the normalized error. In practice, the parameters of a crop-weather model have to be estimated, so a t-distribution is used to represent the forecast error distribution. To determine forecast error confidence intervals, first calculate the normalized forecast error:

$$\frac{Y_0 - y_0}{s_f}, \text{ distributed as } t_{n-k}$$

where,

Y_0 = Actual value of Y for the forecast period

y_0 = Forecast value of Y for the forecast period

s_f = Standard error of the forecast

From this result, forecast error confidence intervals can be estimated around y_0 , the forecast value of Y. The normalized error will have a t-distribution with T - 2 degrees of freedom. For example, a 95 percent forecast error confidence interval for y_0 can be

constructed using the $1 - .95 = 0.05$ or ν probability level of a t-distribution, where $0 < \nu < 1$. The value for ν is obtained from a two-tailed t-distribution table. The resulting forecast confidence interval has a $1 - \nu$ or 95 percent probability of containing Y_0 , the actual value of Y during the forecast period. The 95 percent confidence interval is as follows.

$$y_0 - t_{n-k,0.05} * s_f \leq Y_0 \leq y_0 + t_{n-k,0.05} * s_f$$

Conditional forecasts

A conditional forecast occurs when forecasts of explanatory variables are used to make forecasts of dependent variables. If unconditional forecast error estimates are used when the crop-weather model explanatory variables are not known but instead are forecasted, there is a downward bias in the calculated forecast error. This forecast error equation specification bias is described in Ladd, Duncan and Han (1992). Assuming that the forecast explanatory variables (X_f) are unbiased, the multivariate forecast error variance is:

$$s_f^2 = s^2 * \left[1 + X_f(X'X)^{-1}X_f' \right] + B' * \text{cov}(X_f) * B + \text{tr} \left[s^2 * (X'X)^{-1} * \text{cov}(X_f) \right]$$

where,

$\text{cov}(X_f)$ = Matrix of variances and covariances of the forecast values of X

$\text{tr} \left[\begin{matrix} \bullet \\ \bullet \end{matrix} \right]$ = Trace of the product of the two matrices, $(X'X)^{-1}$ and $\text{cov}(X_f)$

The two additional terms on the right hand side of the multivariate conditional forecast variance equation relative to the unconditional equation come from the formulas for variances and covariances of products of random numbers. These additional terms are necessary because X_f and B are random variables. Since these additional terms have positive values, an underestimate of the forecast error variance will result from using the unconditional estimate when the conditional forecast error estimate is appropriate. Ignoring

the covariances of the forecast explanatory variables when forecast error variances from several forecast dependent variables are aggregated together may result in serious underestimation of the aggregate forecast error.

Although the equation presented by Ladd, Duncan and Han (1992) is the appropriate measure of variance for conditional forecasting, it is of limited use for calculation of forecast distributions. When the explanatory variables are stochastic (i.e., are themselves forecasted values), the predicted values of the endogenous variable (i.e., yield) are not normally distributed, because they are the sum of products of random variables. To overcome this problem, Feldstein (1971) recommended that approximate outer bound confidence intervals for conditional forecasts be calculated using a method based on Chebyshev's inequality (see Pindyck and Rubinfeld, 1991). Feldstein's method represents the effect of the probability distribution of a forecast explanatory variable upon the forecast probability distribution of an endogenous forecasted variable. More information of Feldstein's conditional forecasting method is given below in the "Price Forecasting Procedure" section.

Production forecast error calculation

Before discussing the forecast error calculation method it is recognized that the pooled cross section time series approach used here has implications for the relationship among estimation and forecast errors of districts within a crop-weather model region. The pooled cross section time series estimation approach uses dummy variables to represent the fixed effects for each crop reporting district or cross section in the data set. The standard error of model estimation is assumed to be the same for each of the crop reporting districts within a homogeneous region. The same standard error is used to calculate the forecast error within a region for each individual district. However, even though the standard error of estimation is the same across the districts within a region, the district forecast errors are likely

to vary. These district level forecast errors will vary across the region's districts to the degree that the explanatory variable values for each individual district during the forecast period differ from their respective district average levels during the period of model estimation. As a result, the covariance of yield and production forecast errors across districts within a region cannot be avoided due to the structure of the data set and the dummy variable cross section time series estimation approach taken.

A straight forward aggregation of forecasted production variances to derive overall Corn Belt production forecast distributions can be carried out if there is no covariance of model estimation errors across corn producing regions. However, if model estimation and forecasting errors are not independent across regions, then the forecast variance must be adjusted to account for these covariances. Without these adjustments, serious underestimation of the forecast variance and forecast error may occur.

An alternative method to aggregation of forecast error variances and attempting to account for the region to region forecast covariances is to calculate the variance of the aggregate U.S. corn production forecasts from actual U.S. corn production. This alternative method of deriving forecast error variance is used here.

The forecast variance is calculated by first calculating the difference between the forecast of U.S. corn production from the crop-weather models ($E[PROD_{US}]$) and actual U.S. corn production for each year of model estimation. The value for in-sample predicted U.S. corn production is calculated by aggregating the forecasts of the seventeen crop-weather models and the non-Corn Belt area together to obtain the total U.S. production forecast for each year in the crop-weather model data set. There will be eighteen differences between in-sample estimated and actual U.S. corn production, one for each year used in model estimation (i.e., 1974, 1975, 1976, ..., 1991). These eighteen differences are then squared and summed together, and finally divided by $n - 1 = 18 - 1 = 17$ to derive the forecast variance. This

process is repeated four times, once for each of the crop-weather models (i.e., July 1, August 1, September 1 and October 1).

This method avoids calculation of and adjustment for forecast covariances across the crop-weather model based crop reporting district level forecasts. Arguably, this is the type of forecast variation estimate that applied forecasters will use in estimating the accuracy of their forecasts.

The forecast errors derived from these forecast variances are as follows: 574.9 million bushels for July 1, 242.5 million bushels for August 1, 163.0 million bushels for September 1, and 134.2 million bushels for October 1. These forecast error estimates are compared to USDA forecast confidence intervals for 1992 in Table 12 below. The average difference between the July 1 crop-weather model in-sample forecast and actual production over the 1974-1991 period was -43.4 million bushels, or -0.6% of the 1974-1991 average actual production of 6,970.4 billion bushels. The 1974-1991 in-sample August 1 crop-weather model production forecasts differed from actual production figures on average by -22.5 million bushels, or -0.32% of the 1974-1991 actual average production. September 1 in-sample forecasts for the time period differed from actual production by an average of -19.8 million bushels, or by -0.28%. October 1 forecasts for the time period differed from actual numbers by an average of -18.1 million bushels from the 1974-1991 actual production average, or by -0.26%. These differences are relatively small and indicate the increasing accuracy of the crop-weather model forecasts throughout the growing season as well as the sizable increase in forecast accuracy between the July 1 and August 1 forecasts.

These forecast error estimates will be used in the development of production forecast error confidence intervals and distributions in the sections that follow.

Illustration of the Production Forecasting Procedure

To illustrate the output from this procedure, preharvest U.S. average corn yield and production forecast distributions are derived for the T+1 period of the model (i.e., 1992). Actual 1992 weather conditions are used together with the previously developed regional crop-weather models to derive July 1, August 1, September 1, and October 1 corn production forecast distributions for 1992. The 1992 production results are reported in Table 11. These cumulative probability distributions are derived using the production forecast errors from the previous section and points along the t-distribution. Figure 5 is graphic illustration of the forecast data in Tables 11.

There are large increases in the yield and production forecasts between July 1 and August 1. However, the upper tail of the July 1 distribution and the lower tail of the August 1 forecast distribution do overlap. Historically large July rainfall amounts caused yield forecasts to increase dramatically between July 1 and August 1. Nineteen ninety two was essentially an outlier weather observation year in terms of rainfall. The historically large summer rainfall amounts hurt the forecast accuracy of the crop-weather models, resulting in large forecasting errors.

Table 12 compares the confidence intervals for monthly U.S. corn production forecasts derived from the crop-weather model forecasting procedure developed in this dissertation and those from USDA National Agricultural Statistics Service (NASS) crop production forecasts during the 1992 growing season. Figures 6 and 7 are illustrations of the alternative forecasts in Table 12. The crop-weather model production forecasts showed a quicker response to the large rainfall amounts during July than the USDA forecasts. The USDA production forecast did not rise above 9.0 billion bushels until the November forecast, while the crop-weather model production forecast responded to July rainfall immediately, rising to over 10 billion bushel in the August 1 projection. In comparison, the final U.S. corn

Table 11. 1992 U.S. Corn Production Forecast Cumulative Distributions,
1.0 Billion Bushel Units

Models:				
Probability	July 1	August 1	September 1	October 1
0.5	7.347	9.410	9.839	10.011
1.0	7.491	9.471	9.880	10.045
2.5	7.701	9.560	9.940	10.094
5.0	7.882	9.636	9.991	10.136
10.0	8.091	9.724	10.050	10.185
15.0	8.259	9.795	10.098	10.224
20.0	8.344	9.831	10.122	10.244
25.0	8.442	9.872	10.150	10.267
30.0	8.527	9.908	10.174	10.287
35.0	8.607	9.942	10.196	10.305
40.0	8.683	9.974	10.218	10.323
45.0	8.756	10.004	10.238	10.340
50.0	8.828	10.035	10.259	10.357
55.0	8.900	10.066	10.280	10.374
60.0	8.973	10.096	10.300	10.391
65.0	9.049	10.128	10.322	10.409
70.0	9.129	10.162	10.344	10.427
75.0	9.214	10.198	10.368	10.447
80.0	9.312	10.239	10.396	10.470
85.0	9.397	10.275	10.420	10.490
90.0	9.565	10.346	10.468	10.529
95.0	9.774	10.434	10.527	10.578
97.5	9.955	10.510	10.578	10.620
99.0	10.165	10.599	10.638	10.669
99.5	10.309	10.660	10.679	10.703
Forecast	8.828	10.035	10.259	10.357

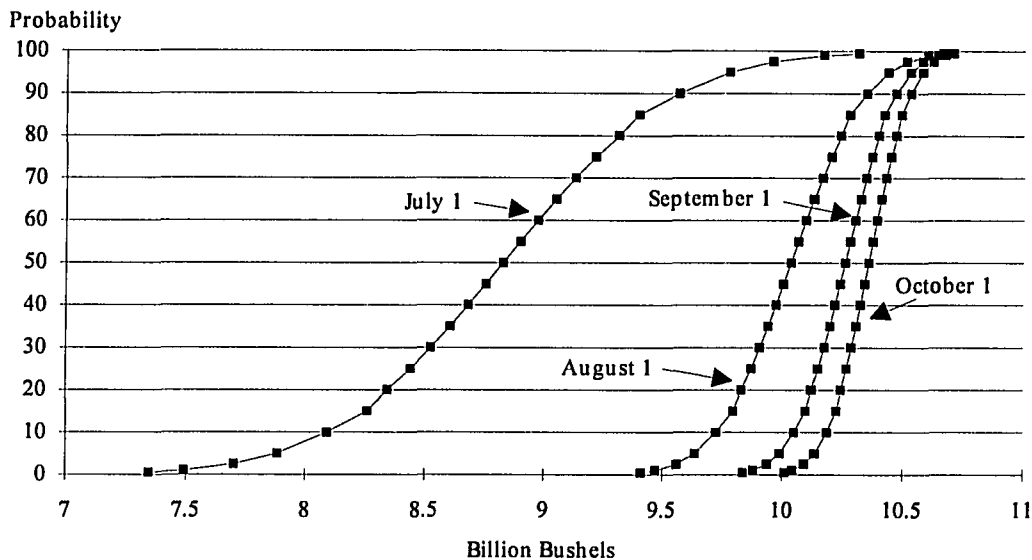


Figure 5. 1992 U.S. Corn Production Forecast Distributions

production forecast was 9.479 billion bushel. Wet harvest conditions and prematurity frost damage in the northern Corn Belt prevented final U.S. corn production from rising even closer to the 10 billion bushel level. Since no variables measuring the yield impact of such prematurity frost damage as occurred in the northern Corn Belt are included in the crop-weather models, this source of forecast inaccuracy is caused by model misspecification. Table 12 also lists the U.S. corn production forecast errors calculated from the in-sample crop-weather model forecasts and the USDA forecast errors. The 1992 USDA forecast errors are based on root mean square percentage forecast errors reported in the 1991 July 1, August 1, September 1 and October 1 USDA crop production reports, respectively. Table 12 results indicate that the crop-weather model production forecast errors are smaller than the reported USDA forecast errors.

The apparent over responsiveness of the crop-weather model yield and production

Table 12. 1992 U.S. Corn Production Forecast Confidence Intervals from Crop-Weather Model and USDA Forecasts (1.0 Billion Bushels)

Crop-Weather Models					
Probability	July 1	August 1	September 1	October 1	November 1
5.0%	7.88	9.64	9.99	10.14	None
17.5%	8.28	9.81	10.10	10.23	None
50.0%	8.83	10.04	10.26	10.36	None
82.5%	9.37	10.26	10.41	10.48	None
95.0%	9.77	10.43	10.53	10.58	None
Forecast Error	0.5749	0.2425	0.1630	0.1342	None
USDA Forecasts					
Probability	July 1	August 1	September 1	October 1	November 1
5.0%	None	7.56	8.01	8.35	8.92
17.5%	None	8.10	8.35	8.61	9.11
50.0%	None	8.76	8.77	8.94	9.33
82.5%	None	9.45	9.19	9.25	9.55
95.0%	None	9.96	9.53	9.53	9.74
RMSE%(91)		7.9%	5.0%	3.8%	2.5%
RMSE Bu.		0.6920	0.4385	0.3397	0.2333

forecasts to high rainfall amounts indicates the need to reestimate the crop-weather models with high rainfall outlier years such as 1992 and 1993 included. Alternatively, different nonlinear rainfall response variables may need to be studied to improve crop-weather model explanatory ability. In contrast, the slowness of 1992 USDA production forecasts to increase in response to the large summer rainfall amounts may be due to cautiousness on the part of USDA forecasters or to concern during that year about the potential magnitude of early frost damage in the Corn Belt.

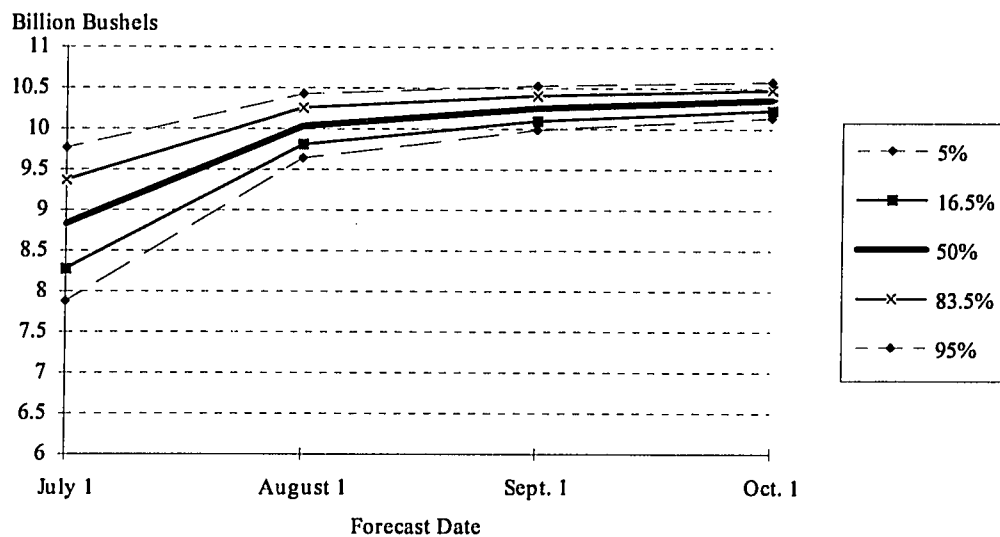


Figure 6. 1992 Crop-Weather Model U.S. Corn Production Forecast Confidence Intervals

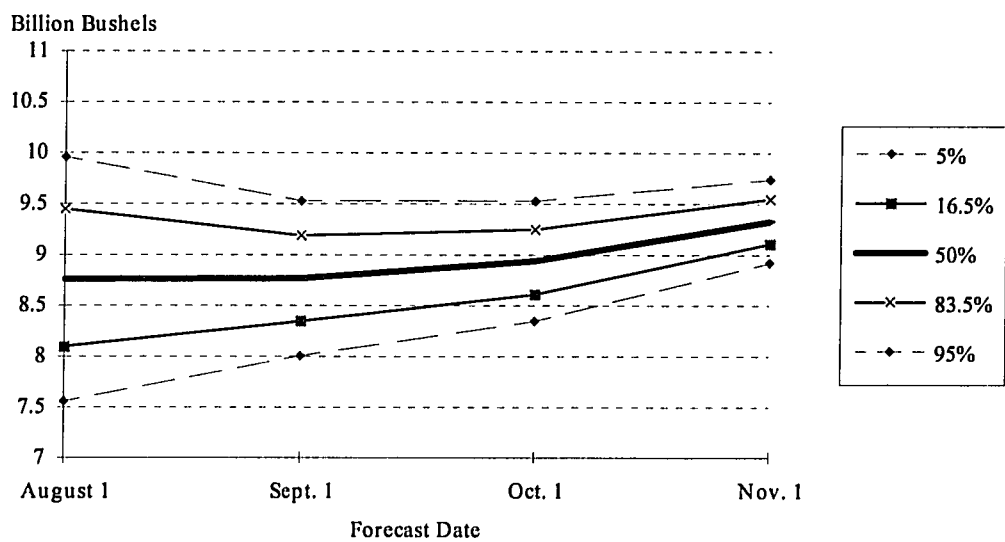


Figure 7. 1992 USDA U.S. Corn Production Forecast Confidence Intervals

CHAPTER 4. FORECASTING HARVEST TIME AVERAGE CORN PRICES

The primary objective of this research is to develop a procedure for forecasting the probability distribution of harvest time average corn prices. Forecasts are made of harvest time average prices instead of season average prices because changes in the amount of corn production have a more direct influence on corn prices at harvest time than during the remainder of the marketing year (September 1 to August 31). During the early part of harvest (mid to late October), participants in the corn market tend to focus on the size of the corn crop and overall supply prospects. After harvest is completed and uncertainty about the size of the corn crop diminishes, the attention of the market shifts away from supply prospects toward export sales and other demand factors. Later in the marketing year (April through August) the corn market switches its focus back to new crop marketing year supply prospects. Because integration of corn production forecast distributions and corn price models is the emphasis of this study, attention will be placed on the time period when new crop corn production prospects will have the most direct impact on prices, i.e., at harvest time.

Preharvest forecasts of harvest time average corn prices will change as forecasts of corn market supply and demand fundamentals change. As discussed above, the projected size of the U.S. corn crop is the primary preharvest fundamental factor affecting harvest time average price forecasts. Other price influencing factors include projected September 1 beginning stocks, feed use, exports, and total use of corn in the old crop marketing year. Forecasts of yields and production are inherently inaccurate prior to critical periods of physiological development for corn, as are preharvest estimates of new crop marketing year beginning stocks, feed use and exports. As time passes more information is known about new crop prospects, typically leading to increasingly more accurate yield, production and

price forecasts, each with successively narrower, more accurate forecast probability distributions. The changing information focus of the U.S. corn market from late spring through harvest is discussed in a "Chronology of the Preharvest Corn Price Determination Process" in Appendix B. To model changes in the preharvest corn market information set and the resulting progressive increase in harvest time corn price forecast accuracy, harvest price forecast probability distributions are calculated using monthly (July 1, August 1, September 1, and October 1) production forecast distributions, each together with the most current USDA corn beginning stocks and utilization estimates for both the current and forthcoming marketing year.

The first step in this procedure of forecasting harvest time average prices will be to estimate a U.S. harvest time average corn price model. Then a method is presented for integrating monthly corn production forecast distributions together with the harvest time average price model. The end result is a procedure for forecasting the probability distribution of U.S. harvest time average prices.

General Approach to Modeling Corn Prices

The harvest time average corn price model is patterned after the reduced form of the Shonkwiler and Maddala dynamic disequilibrium model of U.S. corn prices (1991). The structure of the general Shonkwiler and Maddala switching regressions model is as follows:

$$\begin{array}{lll}
 S_t = a_1 * P_t^* + a_2' * W_t + e_{1t} & a_1 > 0 & \text{(Supply Equation)} \\
 D_t = b_1 * P_t + b_2' * X_t + e_{2t} & b_1 < 0 & \text{(Demand Equation)} \\
 D_t = S_t \text{ if } P_t > P_{t-} & & \text{(Equilibrium Condition)} \\
 D_t < S_t \text{ if } P_t < P_{t-} & & \text{(Disequilibrium Condition)}
 \end{array}$$

where,

S_t = Quantity supplied

D_t = Quantity demanded

P_t = Market-clearing price

P_{t-} = Exogenously set lower limit on price

P_t^* = Rational expectation of price formed when production decisions made

W_t = Vector of supply shifters

X_t = Vector of demand shifters

e_{it} = Estimation errors that are jointly normal with mean zero and covariance

matrix Sigma, $i = 1, 2$

A rational expectations equilibrium solution to this model can be arrived at by setting demand equal to supply, taking expectations of both sides, and solving for the equilibrium price.

$$D_t = S_t \Rightarrow P_t = c_1 + c_2' W_t + c_3' X_t + e_{3t}$$

Shonkwiler and Maddala assumed perfect foresight in knowing whether the market would be in equilibrium or not in their earlier, nondynamic version of the model (1985). They later corrected this assumption (1991) to account for the probability that prices would be in either in equilibrium or disequilibrium.

The Shonkwiler and Maddala model employs an endogenous switching simultaneous system approach in modeling U.S. corn prices. The market is sometimes in equilibrium, and sometimes in disequilibrium. If corn prices are greater than or equal to the U.S. corn support price or are otherwise unconstrained by the government price control, the market is in equilibrium. When corn prices are limited or constrained in their downward movement by the U.S. corn support price (i.e., the effective government farm program loan rate), the

market is in disequilibrium. Whether the market is in equilibrium or in disequilibrium is determined endogenously due to the control on the support price by factors (political entities or policy variables) not otherwise accounted for in the model. Generally, farm and economic policy considerations play a major role in the determination of the U.S. corn support price level.

In this study the U.S. harvest time average corn price model is patterned after the Shonkwiler and Maddala rational expectations equilibrium solution equation. Harvest time corn futures prices are determined as a function of a set of supply and demand shifters. The corn supply at harvest time is in essence an identity with supply equal to the sum of the quantity of U.S. corn production ($PRDN_t$) and new crop marketing year corn beginning stocks ($BGSTKS_t$). A very small amount of corn is annually imported into the U.S., but not enough to significantly impact the corn market. Early in the corn planting and development time period expected new crop corn prices may have had an impact on decisions concerning planted acreage, plant population and fertility programs. However, by harvest the earlier price expectation is no longer a factor. The possible exception would be in the case of extremely low yields where the price level may influence the decision to harvest the crop or not. Therefore, no expected price variable is included in the harvest time supply equation. The demand factors selected are new crop marketing year feed use ($FEED_t$), old crop marketing year total corn use (USE_{t-1}), and new crop marketing year corn exports ($EXPTS_t$). The U.S. corn marketing year begins on September 1 and ends the following August 31. The supply and demand equations and equilibrium conditions based on this set of supply and demand shifters are given below.

Harvest Time Corn Supply Equation:

$$S_t = a_1 * BGSTKS_t + a_2 * PRDN_t + e_{1t}$$

Harvest Time Corn Demand Equation:

$$D_t = b_1 * P_t + b_2 * FEED_t + b_3 * USE_{t-1} + b_4 * EXPTS_t + e_{2t}$$

Harvest Time Equilibrium Condition:

$$D_t = S_t \text{ if } P_t > P_t^-$$

$$\Rightarrow P_t = c_0 + c_1 * PRDN_t + c_2 * BGSTKS_t + c_3 * FEED_t + c_4 * USE_{t-1} + c_5 * EXPTS_t + u_t$$

where,

P_t = December corn futures price at harvest time

$PRDN_t$ = USDA U.S. corn production projection at harvest

$BGSTKS_t$ = USDA beginning stocks projection at harvest

$FEED_t$ = USDA feed use projection at harvest

USE_{t-1} = USDA total corn use projection at harvest for the previous year

$EXPTS_t$ = USDA U.S. corn exports projection at harvest

u_t = estimation error (normally distributed)

All quantity variables measured in 100 million bushels

This corn price model relies on the assumption that fundamental corn supply and demand factors ultimately determine the level of harvest time average corn prices. However, technical market factors may significantly influence the path prices take to arrive at their equilibrium levels. The price to be forecast, the time period for which the forecast is made, and the nature of the price determination process all affect the choice of explanatory data and the type of price model used for model estimation. If harvest time average prices are the variable to be forecasted, then the data used for model estimation must represent the information set available to the market during the harvest time period. If preharvest or postharvest supply and demand information were used for estimating the harvest time model,

the explanatory variables would be subject to measurement errors (in this case, forecasting errors) because they would not represent the actual information set "in the market" at harvest time. This would lead to an econometric errors in variables problem, causing the parameter estimates to be biased (see Judge, et al., 1988, p. 582-585). Therefore, the explanatory variable values available to the market during the harvest period are used for model estimation.

The harvest time average corn price model is estimated for the corn marketing years 1973-1991. U.S. corn exports and prices have been higher and more volatile during this time period than during earlier years. Figures 8 and 9 illustrate the level and volatility of U.S. corn production, exports and marketing year average cash prices since 1960.

The last 15 days of October typically coincide with the first one-half of the U.S. corn harvest. To represent the U.S. harvest time average corn price, average Thursday closing prices during October 15-31 for the nearby December corn futures contract are calculated. By considering futures prices instead of cash prices the potential effect on cash prices of a harvest "glut" or over supply of corn at local elevators and related widening of local basis is avoided. Futures price forecasts can be adjusted to represent cash prices at any U.S. location by using an estimate of local harvest time corn basis.

It is important to note that average harvest time prices are being forecast instead of daily prices during the harvest period, and that the estimate of forecast error variance only applies to the average harvest time price. Daily prices would have a larger variance than average prices (see Ladd, Duncan and Han, 1992).

U.S. corn supply and demand projections are used as explanatory variables in the model. These are available from October and November releases of the USDA World Agricultural Supply and Demand Estimates (WASDE). The variable USE_{t-1} is an estimate of total corn use in the previous (i.e., "old crop") marketing year. Estimates of $BGSTKS_t$,

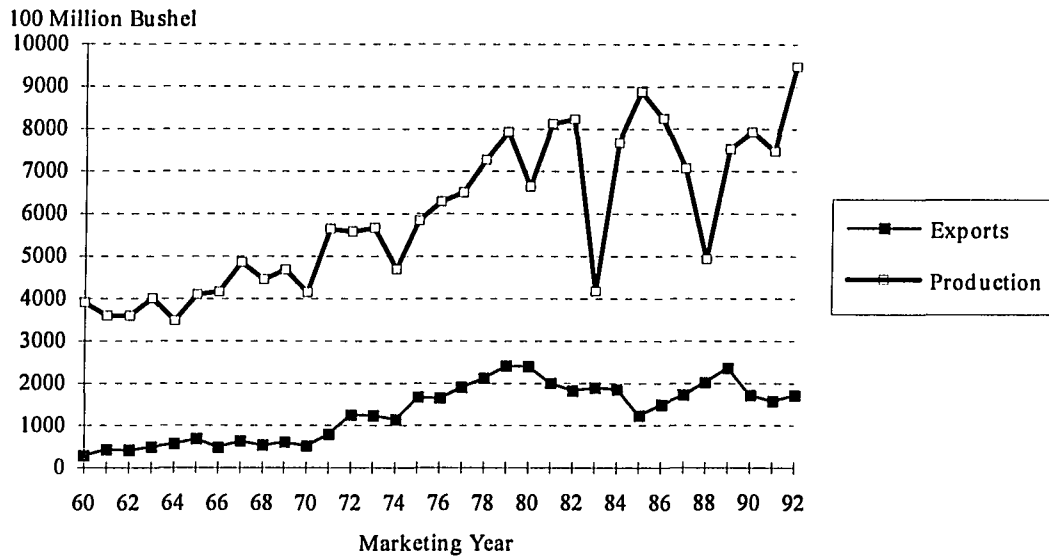


Figure 8. U.S. Corn Production and Exports, 1960-1992

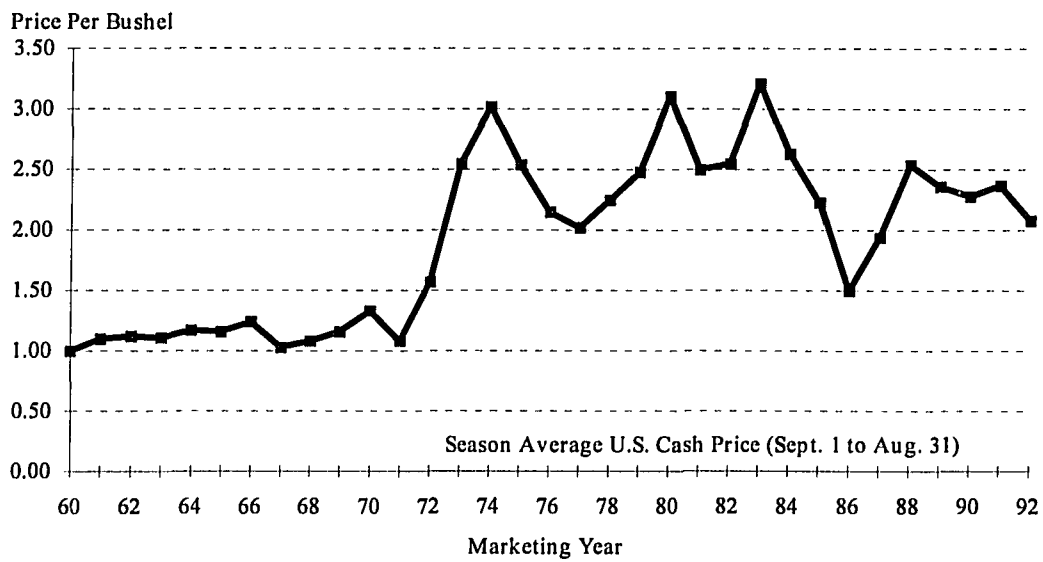


Figure 9. U.S. Season Average Cash Corn Prices, 1960-1992

PRDN_t, FEED_t, and EXPTS_t that are released at harvest time represent projections for the new crop corn marketing year. As stated before, the marketing year for corn is defined as the twelve month time period from September 1 through August 31. The USDA World Agricultural Supply and Demand Board estimates are assumed to be the standard to which private corn market analysts compare their own projections. Therefore, the USDA U.S. corn supply and demand estimates are used as the market's relevant harvest time information set. October WASDE reports have been available since 1976, while November WASDE reports have been available since at least 1970. To form a complete information set from 1973 to the present, the October balance sheets are used back to 1976, and then the November figures are used for 1973-1975. This approach assumes that the October and November WASDE figures are essentially the same for 1973-1975, implying that the market had a general knowledge in these early years of the corn supply and demand situation in October prior to the November estimates. The data used to estimate the U.S. harvest time average corn price model are listed in Table 13. The July, August, September and October, 1992 USDA forecasts of corn supply and demand factors for the 1992-93 corn marketing year are included at the bottom of the table.

Figure 10 is a graphic illustration of harvest time average December corn futures prices, north central Iowa cash grain prices and the U.S. loan rate. The north central Iowa cash corn price is typically \$0.10 lower than the national average cash corn selling price.

A Dickey-Fuller unit root test on the December corn futures price series for the 1973-1991 period rejected the hypothesis of nonstationarity. The Dickey-Fuller test statistic for a 1st degree autoregressive polynomial on the differences was -21.67 for a sample size of 19. The corresponding critical value was approximately -10.2 from Table 8.5.1, p. 371 in Fuller (1976) for a sample size of 25. Because -21.67 is less than -10.2, the hypothesis that the time series of prices is nonstationary is rejected. The validity of employing usual test statistics for

Table 13. U.S. Harvest Time Average Corn Price and Supply/Demand Data,
1973-1991

Corn Marketing Year [#]	Beg. Stocks ##	Prod'n ##	Feed Use ##	Exports ##	Total Use+ Yr (t - 1)	Dec Corn Futures	Cash Price NC IA	Loan Rate (U.S.)
1973-74	7.07	56.78	42.12	11.25	54.95	\$2.48	\$2.17	\$1.05
1974-75	4.81	46.21	34.78	9.00	57.60	3.78	3.41	1.10
1975-76	3.59	57.67	35.64	17.00	48.28	2.87	2.42	1.10
1976-77	3.13	58.65	37.50	15.50	57.29	2.58	2.17	1.50
1977-78	8.76	63.03	37.50	15.50	57.85	2.08	1.67	2.00
1978-79	10.07	68.24	40.00	19.00	58.30	2.32	1.90	2.00
1979-80	12.72	73.90	43.50	25.00	64.70	2.67	2.15	2.10
1980-81	17.01	64.67	42.00	25.50	74.40	3.66	2.95	2.25
1981-82	9.96	80.81	42.50	25.00	74.65	2.90	2.20	2.40
1982-83	21.71	83.15	44.00	22.50	75.75	2.20	1.92	2.55
1983-84	34.34	42.59	40.00	19.25	75.00	3.42	3.07	2.65
1984-85	7.88	74.98	40.00	21.25	68.75	2.78	2.54	2.55
1985-86	13.17	86.03	43.25	16.25	71.75	2.25	2.06	2.55
1986-87	40.38	82.20	42.00	14.00	70.70	1.69	1.41	1.92
1987-88	48.82	71.39	48.00	16.00	67.50	1.84	1.49	1.82
1988-89	42.60	45.50	45.00	17.00	76.25	2.81	2.45	1.77
1989-90	19.30	74.49	42.00	20.00	74.10	2.45	2.16	1.65
1990-91	13.44	80.22	47.00	20.75	75.00	2.30	2.02	1.57
1991-92	15.21	74.79	48.00	16.50	80.95	2.51	2.24	1.62
July 92-93 ###	10.71	84.50	50.00	15.50	78.00			1.72
August 92-93 ###	10.96	87.62	50.00	16.00	78.00			1.72
September 92-93 ###	10.81	87.70	50.00	15.50	78.00			1.72
October 92-93 ###	11.00	89.38	51.50	15.50	78.00	2.09	1.83	1.72

[#] : Corn marketing year = September 1 to August 31

: 100 million bushel units

: USDA forecast for the 1992-93 corn marketing year

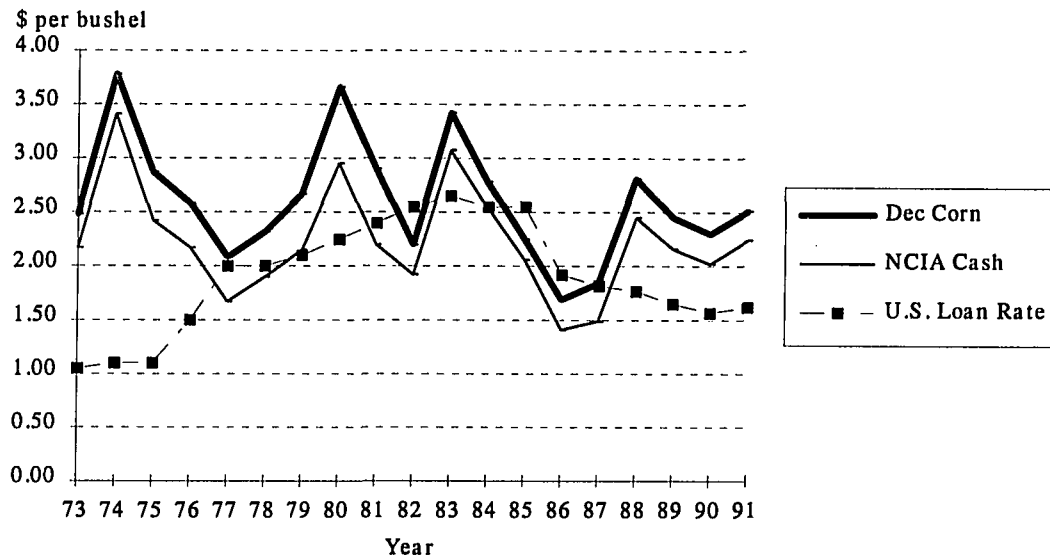


Figure 10. Harvest Time Average Corn Futures, Iowa Cash Prices and U.S. Loan Rate, 1973-1991

the econometric harvest time average corn price model used here is supported by the rejection of the nonstationarity hypothesis.

Harvest Time Average Corn Price Model Estimation Results

The harvest time average corn price model is estimated via OLS for the 1973-1991 time period. The natural logarithm of harvest time prices is used as the dependent variable in model estimation. This transformation creates a semilog model and is consistent with the common assumption that commodity prices are lognormally distributed. If the model estimation error (e) is normally distributed and $P = \text{EXP}(a + bX + e)$, then $\ln(P) = a + bX + e$, where $\ln(P)$ is normally distributed. P is the price, X is the matrix of explanatory variables, a is the constant coefficient, b is the matrix of explanatory variable regression coefficients, and e is the estimation error of the regression. In the case where $\ln(P)$ is normally distributed, P is

distributed lognormally. Lognormally distributed functions are strictly positive, which is a characteristic of commodity prices in general and corn prices in particular. The estimation results are given below (t-ratios in parentheses).

$$\begin{aligned} \ln(P_t) = & 1.3197 - .013418 \cdot \text{PRODN}_t - .0083431 \cdot \text{BGSTKS}_t - .011406 \cdot \text{FEED}_t \\ & (4.15) \quad (-5.55) \quad (-3.39) \quad (-1.03) \\ & + .013081 \cdot \text{USE}_{t-1} + .014605 \cdot \text{EXPTS}_t \\ & (2.95) \quad (2.13) \end{aligned}$$

19 observations (1973-1991)

$R^2 = 0.8154$

Standard Error = 0.10647

Adjusted $R^2 = 0.7443$

Durbin-Watson Statistic = 1.27

The Durbin-Watson statistic was indeterminate with regard to the presence of serial correlation among the model estimation errors. The Jarque-Bera asymptotic Lagrange multiplier test statistic for normality of the model estimation errors is 0.5642, less than the critical chi-square value of 5.991 (2 d.f., 5% probability). Therefore, the hypothesis that the model estimation errors are normally distributed is not rejected (see p. 890-892, Judge, et al., 1988).

The coefficients of this semilog model represent the proportionate rate of change in price per one unit change in the explanatory variable. A one unit change (i.e., a 100 million bushel change in corn production) will have more price impact when prices are high as opposed to when prices are low. For example, a 100 million bushel increase in corn production brings about a \$0.027 decrease in average harvest time prices when prices are originally at \$2.00 per bushel. This is calculated as follows: $\$2.00 \times (-.013418) = -\0.027 . When prices are originally at \$2.61 (the mean of the nontransformed price series), the same

production increase brings about a \$0.035 decrease. When prices are originally at \$3.00 per bushel, a 100 million bushel production increase brings about a \$0.04 price decrease. The price response to changes in other explanatory variables are calculated in the same manner. The antilog of the constant (i.e., $\text{EXP}(1.3197)$) is equal to \$3.74 per bushel.

Examination of the harvest time average corn price model and the associated model residuals during 1973-1991 indicates that harvest time corn futures prices have not been limited in their downward price movement by the government loan rate. This conclusion is based on analysis of price model performance using studentized residuals and DFBETAS (see p. 170-171, Pindyck and Rubinfeld, 1991). Support for this conclusion is given in the explanation of studentized residuals and DFBETAS results given in Tables 14 and 15. Table 14 reports actual and predicted harvest average corn prices along with the calculated and studentized residuals.

Analysis of studentized residuals is used to determine whether there are any outlier observations among the data. The in-sample predicted prices in Table 14 are the antilogs of the natural log prices from the semilog price model.

Outliers in the context of this corn price model are yearly data observations for which the relationship between the price and quantity variables is significantly different from other years for which a model is estimated. Analysis of studentized residuals indicates that the observations for 1974 and 1977 are outliers. Of the two harvest time periods, 1974 is the most extreme outlier. Figure 11 shows actual and estimated prices, with the largest predicted errors during 1974 and 1977.

DFBETAS analysis is used to determine whether any observation has an unusually large influence on the value of a particular parameter in an econometric model. The DFBETAS results in Table 15 indicate that all of the explanatory variable observations in 1974 and three during 1987 (i.e., BGSTKS_t , FEED_t , and USE_{t-1}) have unusually large

Table 14. 1973-1991 Harvest Time Average Corn Price Model Analysis:
Observed and Predicted Values, Calculated and Studentized Residuals

Year	Observed Value (\$/Bu.)	Predicted Value (\$/Bu.)	Calculated Residual	Studentized Residual *
1973	2.48	2.46	0.02	0.08
1974	3.78	3.15	0.63	*2.97
1975	2.87	2.67	0.20	0.74
1976	2.58	2.87	-0.29	-1.10
1977	2.08	2.60	-0.52	*-2.80
1978	2.32	2.47	-0.15	-0.62
1979	2.67	2.55	0.12	0.49
1980	3.66	3.24	0.42	1.36
1981	2.90	2.74	0.16	0.58
1982	2.20	2.32	-0.12	-0.52
1983	3.42	3.55	-0.13	-0.48
1984	2.78	2.72	0.06	0.21
1985	2.25	2.09	0.16	0.78
1986	1.69	1.70	-0.01	-0.08
1987	1.84	1.69	0.15	1.29
1988	2.81	2.96	-0.15	-0.65
1989	2.45	2.56	-0.11	-0.44
1990	2.30	2.41	-0.11	-0.48
1991	2.51	2.56	-0.05	-0.27

* : Studentized residuals greater than 1.96 in absolute value can be regarded as outliers

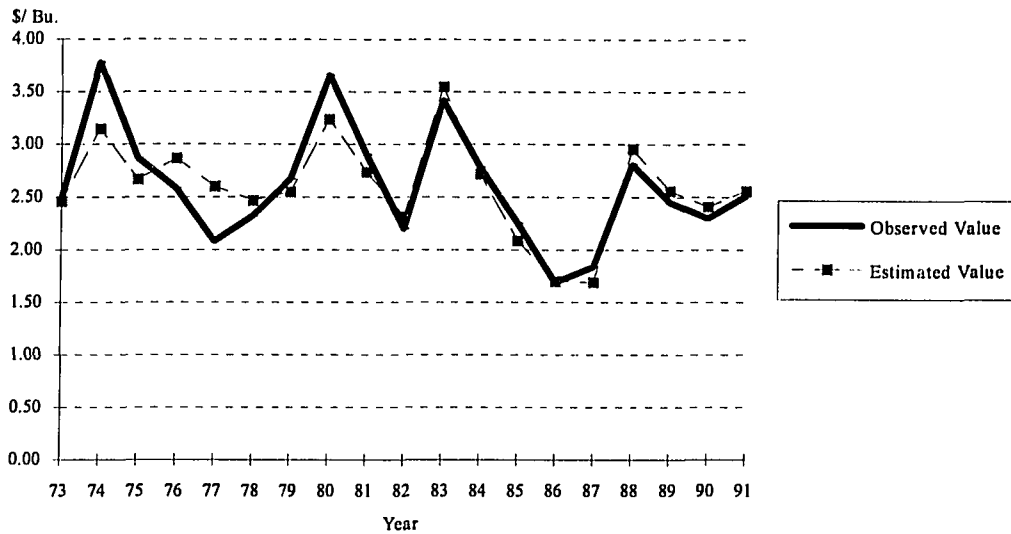


Figure 11. 1973-1991 Harvest Time Average Corn Price Model Performance:
Observed and Estimated Prices

influences on some of the price model parameters. As in the studentized residual analysis, explanatory variable values for 1974 have the most influence on individual model parameters.

Although some individual explanatory variable observations during 1987 had an unusually large influence on three model parameters, that year as a whole was not identified as an outlier year in the studentized residual analysis in Table 14. Some individual explanatory variable observations in 1977, 1980 and 1987 also had unusually large influences on some of the model parameters, although among these only 1977 was identified as being an outlier year from the studentized residual analysis.

The studentized residual analysis results indicate that only two of 19 model residuals (approximately 11%) are considered to be outliers. One of these extreme outlier years (i.e., 1974) was also a high price year, not a harvest time period where the corn loan rate was likely

Table 15. DFBETAS Analysis of 1973-1991 Harvest Time Average Corn Price
Model#

Variables:						
Year	PRODN _t	BGSTKS _t	FEED _t	USE _{t-1}	EXPTS _t	Constant _t
1973	-0.02	-0.03	0.05	-0.03	-0.02	-0.02
1974	*-0.46	*-0.70	*-1.00	*1.13	*-1.70	*1.46
1975	-0.00	0.08	-0.05	-0.34	0.19	0.32
1976	0.07	0.16	0.05	0.05	0.06	-0.22
1977	-0.25	-0.08	*0.45	0.18	0.16	*-0.80
1978	-0.03	-0.02	-0.03	0.18	-0.11	-0.07
1979	-0.04	-0.00	0.14	-0.21	0.26	-0.08
1980	-0.31	-0.05	-0.08	0.14	*0.57	-0.05
1981	0.06	-0.06	-0.07	0.08	0.14	-0.05
1982	-0.12	-0.05	0.06	-0.05	-0.05	0.03
1983	0.25	-0.12	0.15	-0.18	-0.09	-0.14
1984	0.03	-0.01	-0.04	0.03	0.02	0.02
1985	0.31	-0.09	-0.08	0.16	-0.28	-0.06
1986	-0.07	-0.07	0.05	-0.01	0.03	-0.04
1987	0.16	*0.95	*0.63	*-0.93	0.07	-0.24
1988	0.39	-0.13	-0.14	-0.08	-0.02	0.08
1989	-0.09	-0.01	0.09	-0.09	0.01	-0.02
1990	0.02	0.15	-0.18	-0.01	0.01	0.22
1991	0.05	0.17	-0.13	-0.12	0.13	0.19

* : DFBETAS critical value = $[2 / N^{.5}] = [2 / (19)^{.5}] = 0.45$

to limit corn prices from going any lower. Considering the relatively small sample, this finding supports the earlier results of the Jarque-Bera test regarding the normality of the model residuals.

Based on the findings of the analysis of studentized residuals and the DFBETAS statistics, in all but two years during the period of model estimation, harvest time average corn futures prices responded to changes in fundamental supply and demand factors in a consistent manner. If the response of prices to the variables in this model had not been

consistent during this period, then it would be suspected that other factors may have influenced harvest prices. If the outliers were years when cash corn prices were at or near the corn loan rate, that would have been evidence that the U.S. loan rate may have been acting as a price floor, limiting downward cash price movement which in turn would have limited downward futures price movement, causing disequilibrium market conditions. This assumes a somewhat stable basis between harvest time corn cash and futures prices. However, the generally consistent response of harvest time average corn futures prices to these supply and demand factors is evidence that the U.S. corn support price is not a limiting factor for harvest time average corn futures prices. Therefore, all the annual harvest time observations are assumed to be equilibrium market observations and are used in model estimation.

The harvest time average price model results indicate that in general there is a \$0.027 to \$0.04 per bushel decrease in harvest time average corn prices for every 100 million bushel increase in U.S. corn production, depending inversely on the size of the corn production estimate. The ISU Center for Agriculture and Rural Development (CARD) feed grains model assumes a \$0.10 per bushel decrease in season average cash corn price per 100 million bushel corn supply increase. The multiple equation CARD feed grains model arrives at a solution through an iterative process. Therefore, an initial \$0.10 corn price response to a corn supply change may be larger than the final response of corn prices, after feedback adjustments in other factors such as corn usage and the demand for substitute feed grains.

A possible problem with this corn price model is that it does not explicitly account for simultaneity among the explanatory variables. No attempt is made here to model the entire simultaneous system of equations that would reflect the numerous price and quantity adjustments occurring in response to changes in corn production. Implicit in the single equation price model used here is the USDA WASDE method of determining changes in projected corn supply, demand and prices in response to changes in forecast corn production

as reflected in the projections. To imitate the USDA's efforts econometrically would require a complete simultaneous system of equations for determination of corn prices together with various corn supply and demand factors. The negative coefficient for $FEED_t$ in the corn price model is the likely result of the USDA's implicit simultaneous determination of supply, demand, and price. At face value this negative coefficient implies that increased projections of $FEED_t$ in the coming marketing year would have a negative impact on the harvest corn price. What looks like a negative causal relation, with increased $FEED_t$ leading to lower prices (P_t), probably reflects how increased projections of $PRODN_t$ by the USDA cause them to lower their price projection (P_t), which in turn leads them to increase their projection for $FEED_t$.

Price Forecasting Procedure

Monthly aggregate corn production forecasts and forecast errors together with USDA corn supply and demand estimates from the previous month are used in the harvest time average corn price model to estimate price forecast distributions. A Monte Carlo based multivariate application of Feldstein's univariate conditional forecasting procedure is used to derive an approximation of the price forecast distribution.

Forecasted supply and demand data

The explanatory variable values used in each of the four monthly price forecasts during the growing season are obtained by combining the July 1, August 1, September 1, and October 1 crop-weather model corn production forecasts and associated forecast errors together with USDA corn supply and demand estimates from June, July, August and September, respectively. These monthly forecast information sets are the basis for July 1, August 1, September 1, and October 1 price forecast distributions.

Since the early to mid-1970s USDA WASDE estimates of corn supply and demand have been released sometime during the period the eighth to the twelfth of each month. For example, July WASDE estimates of corn supply and demand are released sometime during July 8 to 12. Therefore, an August 1 U.S. harvest time average corn price forecast probability distribution is derived using the most recent USDA WASDE projections (July) and the August 1 U.S. corn production forecast distribution together in the harvest time average corn price model. The September 1 harvest time average corn price forecast distribution is calculated using the August USDA WASDE figures (released August 8-12) together with the September 1 corn production forecast distribution in the harvest time price model. The same approach is used to make price forecasts for July 1 and October 1.

Symmetric variance-covariance matrices of preharvest June, July, August, and September USDA WASDE estimates of $PRDN_t$, $BGSTKS_t$, $FEED_t$, USE_{t-1} , and $EXPTS_t$ with harvest time (i.e., October) estimates are listed in Table 16. The variance-covariance matrices are calculated for different periods of time based on the availability of USDA WASDE reports. In the Monte Carlo conditional forecast simulations the $PRDN_t$ forecast variance derived from the crop-weather models is substituted for the appropriate $PRDN_t$ forecast variance listed in Table 16. The historic June, July, August and September USDA WASDE forecasts are listed in Appendix C. These results indicate that the variance of the forecasts of $PRDN_t$, $BGSTKS_t$, $FEED_t$, USE_{t-1} and $EXPTS_t$ decline as harvest draws near. The large June forecast variance for $PRDN_t$ is indicative of the USDA reliance on trendline yield projections for early season forecasts. Both $BGSTKS_t$ and $FEED_t$ have moderately large covariances with $PRDN_t$ in the June and July forecasts, but markedly smaller covariances with $PRDN_t$ in the August and September forecasts. The relatively large positive covariance of $PRDN_t$ and USE_{t-1} in the June, July and August forecasts implies that growing

Table 16. Variance-Covariance Matrices of Preharvest and Harvest USDA WASDE Projections

	Variables:				
Forecast Period:	PRDN _t	BGSTKS _t	FEED _t	USE _{t-1}	EXPTS _t
A. June to October Forecast Variance-Covariance Matrix (1981-1991)					
PRDN _t	121.32	5.66	-5.58	18.43	0.95
BGSTKS _t		3.47	-3.15	-0.03	0.60
FEED _t			3.55	-0.06	-0.71
USE _{t-1}				5.14	0.60
EXPTS _t					1.05
B. July to October Forecast Variance-Covariance Matrix (1976,77, 79-1991)					
PRDN _t	57.37	6.74	-6.74	10.98	1.17
BGSTKS _t		2.50	-2.33	0.32	0.19
FEED _t			2.50	-0.34	-0.19
USE _{t-1}				4.89	0.42
EXPTS _t					1.11
C. August to October Forecast Variance-Covariance Matrix (1976-1991)					
PRDN _t	10.61	1.65	-1.71	2.53	1.08
BGSTKS _t		1.58	-1.48	-0.06	-0.03
FEED _t			1.58	0.04	0.02
USE _{t-1}				1.39	0.37
EXPTS _t					0.68
D. September to October Forecast Variance-Covariance Matrix (1976-1991)					
PRDN _t	1.13	0.31	-0.24	0.29	0.17
BGSTKS _t		1.14	-1.03	-0.24	-0.09
FEED _t			1.09	0.24	0.09
USE _{t-1}				0.67	0.21
EXPTS _t					0.43

season projections of a large crop lead to expectations of lower prices and subsequently to expectations of increased old crop corn usage. The covariance of $EXPTS_t$ with other forecast variables is small throughout the monthly forecasts. The covariances reported here reflect the adjustments and tradeoffs made by USDA WASDE forecasters in response to changes in supply and demand prospects throughout the corn growing season.

Multivariate conditional forecasting procedure

The multivariate Monte Carlo forecasting approach used here is identical to the univariate approach except for the additional consideration of forecast explanatory variable variances and covariances among multiple forecast explanatory variables. Feldstein (1971) recommended that approximate outer bound confidence intervals for conditional forecasts be calculated using a method based on Chebyshev's inequality (see Pindyck and Rubinfeld, 1991). Feldstein's univariate method represents the effect of the probability distribution of a single forecast explanatory variable upon the forecast probability distribution of an endogeneous forecasted variable. This is carried out by substituting values of the probability distribution of the forecasted explanatory variable ($X_{f,T+1}$) into the forecast model for the endogeneous variable ($Y_{f,T+1}$). The procedure is applied in the following manner in order to calculate a 95% forecast confidence interval from a forecasting model with a single explanatory variable.

1. Calculate the 95% confidence interval associated with the forecast that would be obtained if the forecasted (stochastic) explanatory variable $X_{f,T+1}$ were selected to be two standard deviations (s_x) higher and two standard deviations lower than its forecast value. This confidence interval is derived by calculating both:

$$Y_{f,T+1}^* = a + b (X_{f,T+1} + 2s_x)$$

and

$$Y_{f,T+1}^{**} = a + b (X_{f,T+1} - 2s_x)$$

2. The final 95% prediction interval is the region between $Y_{f,T+1}^*$ and $Y_{f,T+1}^{**}$.

In essence, Feldstein's univariate method uses the forecast confidence intervals for an explanatory variable to derive an approximation of the forecast confidence interval for a forecast dependent variable. Confidence intervals derived by this method will tend to be outer bound estimates, generally wider than the forecast confidence intervals resulting from unconditional forecasting methods relying on known, nonstochastic regressors.

Feldstein's method is the foundation for the Monte Carlo simulation approach to conditional yield, production and harvest time price forecasting used in this dissertation. In this conditional price forecasting application, if there were only one forecast explanatory variable in the forecasting equation (i.e., the univariate case), the probability distribution of the conditionally forecast dependent variable would be estimated via Monte Carlo simulation using the forecast value of the explanatory variable together with its unconditional forecast error and the standard error of the forecast equation. This method differs from Feldstein's in that both the forecast distribution of the explanatory variable and the estimation accuracy of the forecasting equation are accounted for in approximating the distribution of the conditionally forecast dependent variable. Feldstein's conditional forecasting method did not account for forecast equation estimation error, ignoring a potentially important source of forecast variability.

A three step procedure is used to calculate probability distributions of U.S. harvest time average corn price forecasts based on U.S. corn production forecast distributions and

USDA WASDE projections. This procedure to approximate conditional forecast price distributions via Monte Carlo simulation begins by first taking 5000 normally distributed random drawings for each of the forecast explanatory variables (based on their forecast values and associated forecast variance-covariance matrix) and 5000 random drawings of the price model estimation error (based on a zero mean and associated price model standard error). The monthly aggregate $PRDN_t$ forecast value and forecast variance is substituted into the variance-covariance matrix in place of the calculated $PRDN_t$ forecast error from the USDA WASDE projections. Accounting for the forecast explanatory variable variances and covariances allows for the adjustment of $BGSTKS_t$, $FEED_t$, USE_{t-1} , and $EXPTS_t$ to alternative values along the aggregate U.S. $PRDN_t$ forecast distribution. Second, the simulated random values for the explanatory variables and the model estimation error values are together consecutively substituted into the price forecast model to obtain 5000 simulated values of the forecast harvest time average corn futures price. Third, these 5000 simulated price forecasts are arranged in ascending order to approximate the price forecast probability distribution. Price forecast confidence intervals are estimated by a) selecting a confidence level (for example, 90%), b) dividing the confidence level in half to determine the proportion of the probability in each tail of the distribution (ex. $90\% / 2 = 45\%$, implying that 5% of the observations will be in each tail of the distribution), c) multiplying the percent probability in each tail by the total number of Monte Carlo simulations performed (ex. $5000 \times 0.05 = 125$), and d) counting in from each tail the appropriate number of ascending order price observations to determine the values for the upper and lower ends of the confidence interval (ex. lower 5% price forecast at observation 125 and upper 5% price forecast at observation $4875 = 5000 - 125$).

The forecasting process is repeated four times during the corn growing season, coinciding with the dates of the crop-weather model based U.S. corn production forecasts.

From this procedure, harvest time average corn price forecast distributions are estimated for July 1, August 1, September 1, and October 1.

Discussion of price forecasting procedure

The corn price forecasting approach taken here relies on USDA estimates of marketing year corn supply and demand for estimation and forecasting purposes. The USDA WASDE projections are recognized in the corn market, and are readily available at low cost. An alternative approach would be to calculate values for $BGSTKS_t$, $FEED_t$, USE_{t-1} , and $EXPTS_t$ instead of using USDA WASDE projections. However, this approach would be much more costly in terms of the time, money and other resources required for implementation.

Is the response of harvest time average corn prices to the probability distribution of $PRDN_t$ forecasts modeled adequately, especially with regard to possible simultaneity in the determination of the $PRDN_t$, $BGSTKS_t$, $FEED_t$, USE_{t-1} , and $EXPTS_t$? By using the USDA WASDE forecast variance-covariance matrix, an attempt is made to allow for adjustment in the other explanatory variables ($BGSTKS_t$, $FEED_t$, USE_{t-1} , and $EXPTS_t$) in response to alternative values along the $PRDN_t$ forecast distribution. This attempt to adjust for simultaneity in the determination of corn supply and demand factors is an improvement over only adjusting corn prices for changes in $PRDN_t$, ignoring the impact of alternative values for $PRDN_t$ on the other price determining factors which in turn may further effect corn prices.

Illustrated Production and Price Forecast Confidence Intervals

In this section an illustration is given of the association between U.S. corn production forecast confidence intervals and confidence intervals for U.S harvest time average prices.

The 66%, 90% and 95% production forecast confidence intervals for July 1, August 1, September 1 and October 1 presented in part A of Table 17 are based on the crop-weather model corn production forecast error estimates in Table 12.

The U.S. corn production forecast error is multiplied by two times the appropriate t-distribution value for each confidence interval. The 66% forecast error confidence interval represents approximately plus or minus one forecast error from the trendline T+1 period yield forecast. As a result, these U.S. corn production figures represent the difference between the high and low ends of the specific confidence interval. For example, there is a 1,126,000,000 bushel difference between the high and low ends of the 66% July 1 forecast confidence interval. This 66% confidence interval high-low difference decreases to 263,000,000 bushels for the October 1 forecast.

Parts B and C represent production confidence intervals derived from minimum yield forecast errors which are 80% and 60% of the crop-weather model weighted estimates, respectively (i.e., 20% and 40% reductions in forecast error). If yield forecasters could provide more accurate production forecasts than the crop-weather models developed in this study, the tables reflect their impact on production forecast confidence intervals.

Table 18 presents the confidence intervals for USDA 1992 corn production forecasts. These confidence intervals are based on 1991 root mean square errors reported in the USDA National Agricultural Statistics Service crop production reports for August 1, September 1 and October 1. The root mean square errors reported by the USDA are based on the accuracy of the USDA forecasts for the past 20 years. These results are directly comparable to the crop-weather model in-sample prediction error results in section A of Table 17. The August 1 forecast crop-weather model corn production forecast confidence intervals in section A, Table 17 are more accurate than those of the USDA in Table 18 as are the USDA September 1 and October 1 production forecast confidence intervals.

Table 17. U.S. Corn Production Forecast Error Confidence Intervals
for Period T+1 (100,000,000 Bushel Units)

A. Using Crop-Weather Model Forecast Errors

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	11.26	4.75	3.19	2.63
90%	18.91	7.98	5.36	4.42
95%	22.54	9.51	6.39	5.26

B. Using 80% of Crop-Weather Model Forecast Errors

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	9.01	3.80	2.55	2.10
90%	15.13	6.38	4.29	3.53
95%	18.03	7.60	5.11	4.21

C. Using 60% of Crop-Weather Model Forecast Errors

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	6.75	2.85	1.91	1.58
90%	11.35	4.79	3.22	2.65
95%	13.52	5.70	3.83	3.16

Table 18. USDA Forecast Error Confidence Intervals for U.S. Corn Production for 1992 (100,000,000 bushel units)[#]

Confidence Intervals	Forecast Date		
	August 1	September 1	October 1
66%	13.80	8.40	6.40
90%	24.00	15.20	11.80

[#]: Based on 1991 root mean square error percentages and 1992 August 1, September 1 and October 1 forecasts

Table 19 gives the estimated U.S. harvest time average price forecast confidence intervals associated with the results in Table 17. These confidence interval values are calculated by multiplying the confidence interval figures from Table 17 by the estimate of harvest time average corn price responsiveness to changes in U.S. corn production. In the U.S. harvest time average corn price model, for every 100,000,000 bushel increase in corn production, U.S. harvest time average corn prices decreases by 1.34%. This proportional response in harvest time average corn price is multiplied by the production forecast confidence interval high-low differences from Table 17 to estimate the total percentage response of corn prices, with the results reported in Table 19. The associated accuracy of the price forecasts are calculated at \$2.61 per bushel, the harvest time futures average price for 1973-1991. Because price responsiveness is measured in percentage change per 100 million bushels, forecast confidence intervals will be smaller (more accurate) at lower prices and wider (less accurate) at higher prices. Section A of Table 19 is based on section A of Table 17, representing the approximate forecast price interval derived from the original crop-weather model forecast errors. Parts B and C of Table 19 also correspond to the same parts

Table 19. U.S. Harvest Time Average Price Forecast Confidence Intervals
for Period T+1 (Dollars per Bushel)

A. Using Crop-Weather Model Forecast Errors #

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	\$0.39	\$0.17	\$0.11	\$0.09
90%	\$0.66	\$0.28	\$0.19	\$0.15
95%	\$0.79	\$0.33	\$0.22	\$0.18

B. Using 80% of Crop-Weather Model Forecast Errors #

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	\$0.32	\$0.13	\$0.09	\$0.07
90%	\$0.53	\$0.22	\$0.15	\$0.12
95%	\$0.63	\$0.27	\$0.18	\$0.15

C. Using 60% of Crop-Weather Model Forecast Errors #

Forecast Date				
Confidence Intervals	July 1	August 1	September 1	October 1
66%	\$0.24	\$0.10	\$0.07	\$0.06
90%	\$0.40	\$0.17	\$0.11	\$0.09
95%	\$0.47	\$0.20	\$0.13	\$0.11

#: Proportional price change from \$2.61, mean of the harvest time average futures price for 1973-1991

in Table 17, representing price forecast intervals based on yield and production intervals that are 80% and 60% as wide as the crop-weather model estimates, respectively. For example, the July 1 66% harvest time average corn price confidence interval from the crop-weather model (part A of Table 19) is estimated to be \$0.39. By October 1, the 66% confidence interval has decreased to \$0.09.

The results in Tables 17 and 19 indicate the impact of harvest time corn price forecast precision on improved forecasts of U.S. corn production. A 20% increase in the accuracy of the July 1 U.S. corn production forecast results in a \$0.07 decrease in the 66% price forecast confidence interval, from \$0.39 to \$0.32. A 40% increase in July 1 yield forecast accuracy results in a further \$0.08 decrease in the 66% price forecast interval, from \$0.32 to \$0.24. From the July 1 to the August 1, September 1 and October 1 forecasts, the consecutive decreases in harvest time average price forecast intervals from improved yield forecast accuracy become smaller. For example, the October 1 66% minimum forecast confidence interval based on the crop-weather model estimates is \$0.09, compared to \$0.07 and \$0.06 from forecasts that are both 20% and 40% more accurate.

Table 20 illustrates harvest time corn price forecast confidence intervals derived from the USDA production forecast confidence intervals in Table 18. The narrowing of price forecast confidence intervals for September 1 and October 1 compared to August 1 in Table 20 follow directly from the narrower production forecast confidence intervals for these monthly forecasts in Table 18.

It can be concluded from these results that the crop-weather model production forecasts are more accurate than those from the USDA. With additional improvements in crop-weather models and the inclusion of recent outlier years such as 1992 and 1993 in crop-weather model data set, the potential exists for substantial gains in forecast accuracy from using crop-weather forecasts.

Table 20. U.S. Harvest Time Average Prices Forecast Confidence Intervals for 1992
Based on USDA Corn Production Forecast Error Confidence Intervals[#]

Confidence Intervals	Forecast Date		
	August 1	September 1	October 1
66%	\$0.48	\$0.29	\$0.22
90%	\$0.84	\$0.53	\$0.41

[#]: Proportional price change from \$2.61, mean of the harvest time average futures price for 1973-1991

Forecasts using 1992 crop-weather model results and USDA WASDE projections

The 1992 harvest time price forecast distributions for July 1, August 1, September 1, and October 1 are given in Table 21. Figure 12 graphically illustrates the price forecast distributions given in Table 21. Table 22 and Figure 13 illustrate the difference between 1992 price forecast confidence intervals based on the corn production forecasts from the crop-weather models and those based on production projections and confidence intervals reported by the USDA.

In Table 21 forecast prices below the announced 1992 U.S. loan rate of \$1.72 per bushel are marked with a "#". The U.S. loan rate most directly effects local cash prices rather than futures prices. In order to indicate the possible impact of the loan rate on futures price forecast distributions the extreme case of a zero futures-cash differential is used. A zero basis does occur in some parts of the midwest, but typically not in the majority of Corn Belt regions. Although the sections of the forecast price distributions below the loan rate are shown in the table, it is highly unlikely that they would ever be realized. This price forecast distribution truncation is illustrated in Figure 12.

Table 21. 1992 U.S. Harvest Time Corn Price Forecast Cumulative Distributions
(Corn Futures Prices, Dollars Per Bushel)

Models:				
Probability	July 1	August 1	September 1	October 1
0.5	# \$1.54	# \$1.30	# \$1.26	# \$1.24
1.0	# 1.58	# 1.34	# 1.29	# 1.27
2.5	# 1.65	# 1.39	# 1.35	# 1.33
5.0	# 1.71	# 1.46	# 1.41	# 1.38
10.0	1.79	# 1.52	# 1.47	# 1.44
15.0	1.84	# 1.56	# 1.51	# 1.47
20.0	1.87	# 1.60	# 1.54	# 1.50
25.0	1.91	# 1.63	# 1.57	# 1.53
30.0	1.94	# 1.66	# 1.60	# 1.55
35.0	1.97	# 1.68	# 1.63	# 1.58
40.0	2.00	# 1.71	# 1.65	# 1.60
45.0	2.03	1.73	# 1.68	# 1.62
50.0	2.06	1.76	# 1.70	# 1.65
55.0	2.09	1.79	# 1.72	# 1.67
60.0	2.13	1.82	1.75	# 1.69
65.0	2.16	1.84	1.78	# 1.72
70.0	2.19	1.87	1.81	1.75
75.0	2.23	1.90	1.84	1.77
80.0	2.27	1.94	1.87	1.81
85.0	2.32	1.98	1.92	1.84
90.0	2.39	2.05	1.97	1.89
95.0	2.48	2.14	2.05	1.97
97.5	2.59	2.20	2.12	2.05
99.0	2.68	2.30	2.21	2.11
99.5	2.73	2.35	2.27	2.15
Average \$	\$2.08	\$1.77	\$1.71	\$1.66

#: At or below announced national corn loan rate of \$1.72 per bushel

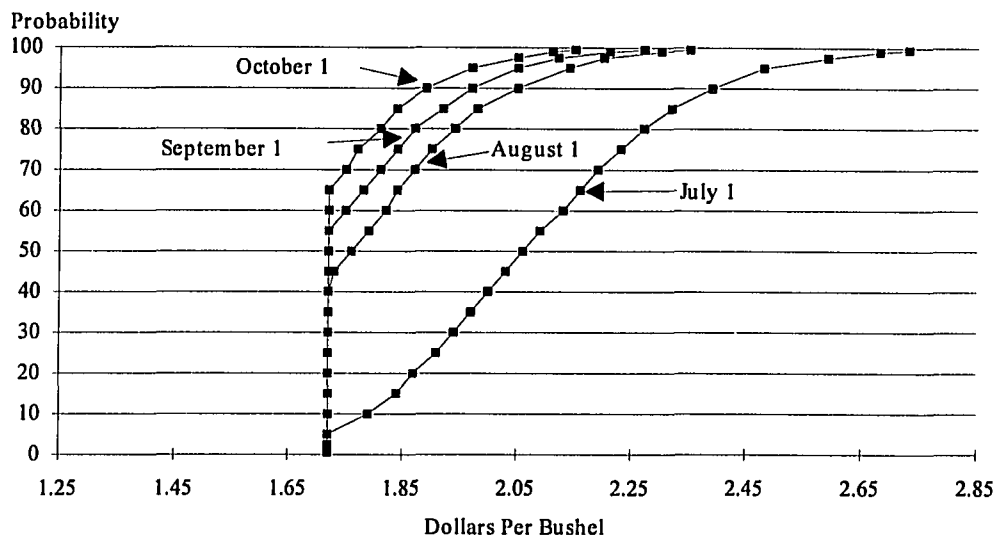


Figure 12. 1992 U.S. Harvest Time Average Corn Prices Forecast Distributions

The accuracy of the 1992 price forecasts from the procedure presented in this paper are directly related to the accuracy of the U.S. corn production forecasts from the crop-weather models. A variety of factors caused the August 1, September 1 and October 1 U.S. corn production forecasts from the crop-weather models to be much larger than actual 1992 production.

Table 22 and Figure 13 show that price forecasts based on the 1992 crop-weather model production projections are generally lower than those based on USDA production forecasts, due mainly to the larger forecasts of 1992 corn production from the crop-weather model procedure. The USDA forecast based price confidence intervals utilized the forecast of production and the forecast variance as listed in Table 16 instead of the root mean square error based confidence intervals illustrated in Tables 12 and 18. Actual 1992 harvest time average corn futures prices were \$2.09 (see Table 13).

Table 22. 1992 U.S. Harvest Time Corn Price Forecast Confidence Intervals from Crop-Weather Models and USDA Forecasts (Dollars per Bushel)

Crop Weather Models:				
Probability	July 1	August 1	September 1	October 1
5.0%	# \$1.71	# \$1.46	# \$1.41	# \$1.38
17.5%	1.84	# 1.58	# 1.52	# 1.48
50.0%	2.06	1.77	# 1.70	# 1.65
82.5%	2.30	1.97	1.90	1.83
95.0%	2.48	2.14	2.05	1.97
Average \$	\$2.08	\$1.77	# \$1.71	# \$1.66
USDA Projections:				
Probability	July 1	August 1	September 1	October 1
5.0%	None	# \$1.68	\$1.73	# \$1.68
17.5%	None	1.85	1.87	1.80
50.0%	None	2.09	2.08	1.99
82.5%	None	2.37	2.31	2.20
95.0%	None	2.60	2.50	2.37
Average \$	None	\$2.11	\$2.09	\$2.00

#: At or below announced national corn loan rate of \$1.72 per bushel

Most of the improvement in 1992 forecast error for production and prices in this forecasting procedure occurred between the July 1 and August 1 forecasts. In a normal year more improvement in forecast accuracy may have occurred in later months. However, abnormally large rainfall amounts during 1992 reduced the accuracy of the crop-weather corn yield and production forecasts, which in turn hurt price forecast accuracy.

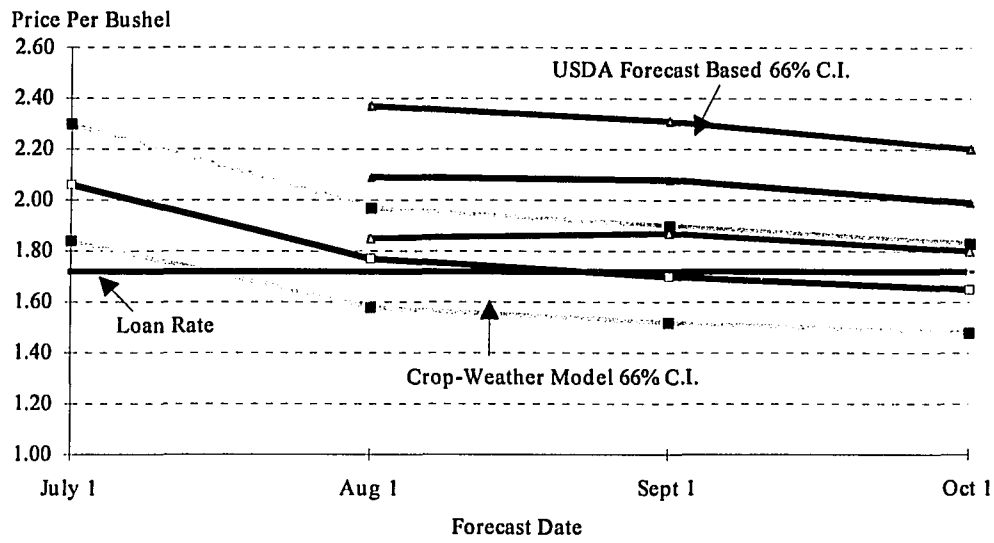


Figure 13. 1992 Comparison of Derived USDA and Crop-Weather Model Confidence Intervals for Harvest Time Average Corn Prices

CHAPTER 5. CONCLUSIONS

The main objective of this dissertation is to improve the probabilistic content of grain price forecasts by developing a technique for calculating U.S. harvest time average corn price forecast distributions. This objective has been met through development of a three step forecasting procedure. First, crop-weather model yield forecasts for crop reporting districts are transformed into production forecasts, which are then aggregated together to form national corn production forecast. Second, measures of historic forecast accuracy are used to calculate national corn production forecast distributions and confidence intervals. Third, aggregate U.S. production forecast distributions are used in a corn price model to develop average harvest time corn price forecast distributions. This procedure contributes towards forecaster's efforts to account for uncertainty both in preharvest crop production projections and in the determination of grain prices in estimating the probability of alternative grain price outcomes. As a result of developing this forecasting procedure, a better understanding has been gained of how the accumulation of weather and supply/demand information throughout the U.S. corn growing season affects the accuracy of preharvest corn yield, production and price forecasts.

This dissertation research extends Thompson's crop-weather model (1986) in three ways. First, the use of intramonthly weather data during July and August instead of monthly weather explanatory variables as in Thompson's model accounts for the temporal distribution of weather conditions throughout these critical periods of corn development. Crop-weather models estimated with intramonthly weather data for July and August have on average a three to four percent higher R^2 and approximately one half bushel smaller standard error compared to the same models estimated with monthly data. Thompson's work is confirmed and

extended by using aridity indices to measure the yield impacts of weather extremes and of simultaneously occurring combinations of extreme weather conditions. Whereas Thompson's results showed a decline in the responsiveness of corn yields to weather conditions at extreme levels, so do the aridity indices results of this study, particularly to excessive moisture during July in the eastern Corn Belt. These crop-weather models measure the impact on corn yields of jointly occurring weather extremes while Thompson's results did not. The combination of extreme hot and dry conditions occurring together during July have a significant negative yield impact in some Corn Belt areas. However, differences in the yield effects of some of the aridity index variables are noted in various parts of the Corn Belt. Third, estimation of separate crop-weather models for homogeneous corn production regions throughout the U.S. Corn Belt as opposed to using existing state boundaries is a departure from the approach of Thompson and others. The five states in Thompson's study (Illinois, Indiana, Iowa, Missouri and Ohio) are subdivided into eight homogenous regions, parts of which extend into other states as well. Along with these three Thompson model extensions, the cross section time series approach to crop-weather model estimation is a modification of other methods relying on longer data series which are more likely to be affected by structural change over time due to advancements in plant genetics, more effective tillage practices and crop pesticides and climatic variation. Another contribution of this research is that crop-weather models are estimated successively during the growing season (i.e., July 1, August 1, September 1 and October 1) as opposed to the usual practice of estimating one model for the whole growing season.

The harvest time average corn price model used in this study is based on the dynamic disequilibrium switching regressions model of Shonkwiler and Maddala (1991). Examination of the harvest time average corn price model parameters and estimation errors indicates that the U.S. corn loan rate did not cause nearby December corn futures prices at

harvest time to be in a disequilibrium state during the 1974-1991 period. The model estimation results confirm the significant negative relationship between harvest time corn prices and changes in corn production. This price model is used together with the corn production forecast distributions and government estimates of other supply and demand shifters to derive harvest time average corn price forecast distributions. The Monte Carlo based multivariate application of Feldstein's univariate conditional forecasting procedure used in this dissertation is unique and a contribution to the applied forecasting literature.

By calculating the probability distribution of price forecasts instead of the common approach of forecasting only average prices, the probabilistic content of forecasts is improved. Analysis of U.S. corn production and harvest time price forecast confidence intervals implied by this forecasting procedure indicate improvements in corn production forecast accuracy throughout the corn growing season. The sixty-six percent forecast error confidence interval for these crop-weather and harvest time corn price models narrows by \$0.30 per bushel from the July 1 to the October 1 crop-weather model projections (see Table 19). The ninety five percent forecast error confidence interval narrows by \$0.61 during the same time period. The price forecast confidence intervals derived from successive crop-weather model production forecasts are comparable with those based on historic USDA forecast accuracy. The size of the 66% price forecast confidence intervals for July 1, August 1, September 1 and October 1 for 1992 from the crop-weather models are \$0.46, \$0.39, \$0.38 and \$0.35, respectively. Similar figures based on USDA production forecast accuracy for August 1, September 1 and October 1 were \$0.52, \$0.44 and \$0.33, respectively (see Table 22).

Future research in this area should focus on improving the forecast accuracy of both the crop-weather models and the corn price model. Crop-weather model related research should focus on specifically accounting for the stage of crop development in determining the

impact of weather conditions on corn yield. Also, better methods need to be developed for the selection and testing of the critical yield influencing levels for aridity index variables in crop-weather models, and of modeling nonlinear yield responses to weather variables. The explanatory ability of this particular crop-weather model and others may be improved by adding explanatory variables which measure the yield effects of early frost and poor harvest conditions, as well as utilizing weekly crop conditions reports. Crop condition reports will become more usable for yield prediction as the number of years for which they are available increases. Price model performance may be improved by examining additional ways of accounting for simultaneity among explanatory variables (by using estimation methods such as two or three stage least squares) and by utilizing alternative nonlinear functional forms with attention given to their distributional properties.

An interesting comparison could be made between these price forecast distributions and the price probability distributions implied by corn options market premiums. This comparison could provide valuable information regarding the accuracy of the collective judgment of futures and options traders with regard to preharvest crop and price prospects. Also, these forecast distributions could provide probability based information on which grain marketing strategies then could be based.

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APPENDIX A.

CLUSTER ANALYSIS USING WARD'S METHOD

Ward's heirarchical clustering scheme is based on the evaluation of squared Euclidian distances between vectors of numerical information. The formula used is as follows:

$$d(X_i, X_j) = (X_i - X_j)' (X_i - X_j)$$

where,

$d(X_i, X_j)$ = the squared Euclidian distance between two numerical data vectors
(i.e., between the numerical values of yield and weather data in the
i'th and j'th crop reporting districts)

X_i = the i'th vector of data (i.e., the i'th crop reporting district yield and
weather data vector)

X_j = the j'th vector of data (i.e., the j'th crop reporting district yield and
weather data vector)

In this application of Ward's method, the vectors for the crop reporting districts may contain either yields alone or yields together with weather data for that district over time.

Ward's method of heirarchical clustering progresses in a stepwise manner to accomplish the grouping of the crop reporting districts. Ward's algorithm begins by computing and storing a matrix of squared Euclidian distances between every possible pair of CRDs. Each observation begins in a cluster by itself. The two closest clusters in terms of Euclidian distance are merged to form a new cluster, replacing the two old clusters. Successive merging of old with new clusters is repeated until only one cluster is left, containing all the CRDs. At each step of the clustering/grouping process, the sum of squares is minimized over all partitions obtainable by the merging of two clusters from the previous

cluster generation. Ward (1963) suggested that this method provides an analysis of the loss of information resulting from the grouping of individuals into clusters. This loss of information can be measured as the sum of the squared deviations from the mean of the cluster to which every point belongs. At each step in the analysis, the union of every possible pair of clusters is considered. Then the two clusters whose fusion results in the minimum loss of information are combined.

APPENDIX B.
CHRONOLOGY OF THE PREHARVEST CORN PRICE
DETERMINATION PROCESS

During the U.S. corn growing season grain market fundamentals are subject to continual change. As the growing season progresses more information becomes available about the prospects for U.S. crop production and corn usage. A chronology is presented below of the preharvest events that affect corn market fundamentals. This arrangement of corn market information in the order of its availability is similar to the procedure for corn production and price determination developed in this dissertation.

Stage 1: Early summer (June)

June weather conditions affect the outlook for U.S. corn production. However, the market is aware that the critical periods for corn development are still ahead. These future critical periods are silking and pollination during July and ear fill during August and September. May planting problems, soil conditions, and current weather all affect prospects for corn production and therefore harvest time price prospects.

Old crop corn carryover forecasts are affected primarily by estimates of feed use and exports for the remainder of the old crop marketing year. Summer feed use estimates are made more accurate by the release of the June 1 Hogs and Pigs report. Summer cattle feeding forecasts and feed use estimates are based on the April 1 Quarterly Cattle on Feed report and the May and June Monthly Cattle on Feed reports. Poultry production and feed use can be reliably estimated from reports of hatchings and other market information. Summer grain exports are forecast using the amount of export purchases to date during the

marketing year, predelivery export bookings for the remainder of the summer, and information about crop prospects in both grain importing and competitor exporting countries. Note that if buyers purchase grain "hand to mouth" and become reactive to U.S. summer crop prospects, export bookings may not be a reliable figure to use for export sales forecasts.

New crop corn supply prospects during June are based on estimates of planted acreage, subsoil moisture availability in the Corn Belt, deviations from normal crop development, and current rainfall and temperature conditions. Old crop supply will be specified in the June 1 quarterly stock report, released in late June.

New crop corn demand prospects are affected by the prospects for feed use during the coming marketing year. Feed use will depend on expected livestock numbers. The estimates of the spring pig crop and of summer and fall farrowings from the June 1 Hogs and Pigs report lead to projected hog marketings for the fall, winter and spring. Cattle marketings cannot be projected very far beyond the fall to early winter periods based on the April 1 Quarterly Cattle On Feed report. Poultry production can be forecast with a fair amount of accuracy based on its consistent pattern of growth over time. Much uncertainty remains concerning new crop marketing year export prospects. More information is known about the crop production outlook in major corn importing and exporting countries, but considerable uncertainty still exists. Political occurrences and policy decisions may affect the outlook for corn exports. Food, seed and industrial (FSI) use estimates have been fairly predictable, following a steady growth pattern. Unless governmental changes in ethanol subsidization occur, or some other political or health issue becomes prominent that effects the grain supply and demand situation, the amount of FSI use would not be very volatile and therefore have a major influence on the grain market.

Stage 2: Pollination and Silking (July)

During this critical time of corn development, a period of high temperatures combined with windy conditions and limited rainfall can severely damage the crop. Damage during this time can offset the beneficial effects of excellent crop development conditions earlier in the growing season. Severe July weather conditions can leave well-developed corn stalks barren of kernels if a hot, dry wind scorches corn plants during the pollination phase. A "weather market" is likely to occur during this period when the attention of grain traders is focused on weather conditions and their potential impact on crop prospects.

The markets' expectation of old crop corn supply is still largely based on the June 1 quarterly stocks estimate, released in late June. Estimates of old crop corn feed use continue to be based on livestock feeding estimates from recent government reports, especially the June 1 Hogs and Pigs report and the July 1 Quarterly Cattle on Feed report. However, in the event of a developing short crop scenario, late summer feed use could be drastically reduced as a result of sharply higher feed prices. Through previous export bookings, a large component of July exports is already determined. There may be some increase in export purchases in the event of a developing short crop scenario, especially if world supplies of feed grains are low and importing countries respond by aggressively bidding for remaining world supplies.

Prospects for new crop corn supplies are very sensitive to current weather and crop conditions. The July 1 USDA Corn Production estimate is based on trend line yield forecasts and not on actual field survey results. Therefore the July 1 production estimate may not have a large impact on grain market prices. Expectations for new crop corn demand are influenced by the July 1 Quarterly Cattle on Feed report released in late July. From this report a projection of cattle feedlot feed use will be made for the remainder of the summer and on into the last quarter of the calendar year. The June 1 Hogs and Pigs report still is a basis for

projections of hog numbers and Feed Use through the second quarter of the coming calendar year (5/6th of the coming corn marketing year). Poultry feed use is likely to be predictable following the consistent pattern of poultry production. New crop corn exports become more predictable as U.S. crop prospects become known. More information is known about crop prospects and corn needs in the major importing and exporting countries for the next coming marketing year at this time than during June. Given the USDA's world wide system of attachés and trade envoys, the government's estimate of U.S. corn exports for the coming year may be the best export forecast information available to the market. FSI may be projected in the same manner as was done in June.

Stage 3: Ear fill to crop maturity (August -- September)

During August and September the U.S. corn crop can still be damaged by hot, dry conditions that could reduce the degree to which kernels/ears "fill", lowering corn yields. In September, the corn market becomes sensitive to threats of an early frost. This is especially true if the crop is lagging behind its normal level or rate of maturity, due either to planting problems, to an unusually cool growing season or both. However, the corn yields are less sensitive to high temperatures and dry conditions than during July.

The old crop marketing year ends on August 31. The September 1 quarterly stocks report is released in late September. Anticipation of the results of the report and trader's reaction to the final old crop estimates could affect the market.

New crop supply prospects will be affected by August and September weather conditions. The USDA crop production reports in mid-August and mid-September may lead to volatile grain prices if they project corn production to be far different than prereport expectations. The August 1 report is the first USDA production estimate of the growing season to be based on field survey data. New crop corn feed use projections may be affected

by the USDA September 1 Hogs and Pigs report. Indications of especially large or small numbers of hogs on feed and/or swine breeding herd expansion or contraction would give a signal to the corn market concerning feed use in the upcoming marketing year. The grain market reaction to major surprises in the Hog and Pigs report would occur after the report is released in late September. The August and September Monthly 7-State Cattle on Feed reports are released during this time, signaling feed demand for the next one to two quarters. Poultry feed use will likely remain consistent. With the start of a new corn marketing year as of September 1 and the increased certainty about the size of the U.S. corn crop, the attention of the market increasingly shifts toward export sales. Growing conditions in the world's major wheat and feed grain production regions are watched closely during this critical crop development time in the U.S.. World political developments may also affect the corn market during this time, especially any news of increased export credits for grain by the U.S. or other major exporting countries, alternative forms of subsidized sales, and/or export embargoes. Essentially, as uncertainty about the size of the U.S. crop diminishes, the market's attention shifts away from U.S. growing conditions toward other market influencing factors.

Stage 4: Harvest (October -- November)

By harvest time the accuracy of most corn production forecasts increases greatly, reducing the uncertainty about total available supplies for the coming marketing year. The market turns its attention to issues and events affecting demand for corn and other feed grains. Harvest delays and grain transportation problems could potentially have an impact on the market. Abnormally wet harvest conditions, a lack of storage at country elevators, a shortage of rail cars for grain transport or an early end to barge traffic on U.S. rivers for the winter all could potentially affect harvest time average corn prices.

APPENDIX C

USDA WASDE PREHARVEST SUPPLY AND DEMAND FORECASTS

A. June Forecasts, 1981-1993 (100 Million Bushels)

Date	PRDN _t	BGSTKS _t	USE _{t-1}	FEED _t	EXPTS _t
6-30-81	74.97	8.16	74.50	41.00	25.00
6-23-82	76.85	19.26	73.10	44.00	23.00
6-23-83	60.50	33.34	73.50	44.50	21.00
6-22-84	79.25	5.12	67.75	41.50	20.25
6-10-85	78.75	11.81	72.00	43.00	17.00
6-10-86	75.75	39.86	65.30	42.00	16.25
6-9-87	72.00	51.15	71.80	46.50	16.00
6-9-88	73.00	41.13	78.36	50.00	17.50
6-12-89	78.50	18.30	74.50	42.20	19.50
6-12-90	81.00	12.80	81.80	46.50	22.00
6-11-91	82.75	14.00	78.80	49.50	17.50
6-10-92	85.75	11.21	78.95	50.00	15.50
6-10-93	85.00	21.13	84.70	54.00	15.50

B. July Forecasts, 1976, 1977, 1979-1993
(100 Million Bushels)

Date	PRDN _t	BGSTKS _t	USE _{t-1}	FEED _t	EXPTS _t
7-13-76	65.53	3.13	58.15	41.15	14.50
7-13-77	63.30	8.98	57.15	37.99	14.50
# 7-XX-78	N.A.	N.A.	N.A.	N.A.	N.A.
7-13-79	66.63	13.12	68.75	42.50	24.00
7-14-80	72.84	16.76	73.75	43.50	26.00
7-13-81	71.16	8.66	74.00	39.50	25.00
7-13-82	76.85	19.26	73.10	44.00	23.50
7-13-83	62.00	33.84	73.00	45.00	20.50
7-11-84	78.10	5.12	67.75	41.50	19.75
7-10-85	80.75	12.32	71.50	43.00	17.00
7-11-86	79.10	40.13	65.05	42.00	15.50
7-9-87	71.50	49.54	73.41	47.00	16.00
7-12-88	52.00	43.65	75.86	43.00	16.50
7-12-89	74.50	18.30	73.55	42.00	19.50
7-12-90	78.50	12.80	81.80	45.50	21.50
7-11-91	82.75	14.75	78.05	49.50	17.50
7-9-92	84.50	10.71	79.45	50.00	15.50
7-12-93	78.50	21.24	84.60	53.00	15.00

#: Information and exact date not available.

C. August Forecasts, 1976-1993
(100 Million Bushels)

Date	PRDN _t	BGSTKS _t	USE _{t-1}	FEED _t	EXPTS _t
8-13-76	61.87	3.13	58.15	39.00	15.50
8-12-77	60.92	9.01	57.15	37.50	14.50
8-11-78	65.03	11.07	61.50	40.00	17.50
8-13-79	71.09	12.37	69.50	43.00	25.00
8-12-80	64.46	17.01	73.50	41.50	25.00
8-13-81	77.35	10.16	72.75	42.00	24.50
8-12-82	83.15	20.76	71.60	44.00	23.50
8-12-83	52.37	34.34	72.50	42.50	20.00
8-13-84	76.68	5.87	67.00	41.00	20.50
8-12-85	82.66	12.42	71.40	43.25	17.00
8-12-86	83.16	40.13	65.05	42.50	15.50
8-11-87	72.31	49.29	73.66	47.00	16.00
8-12-88	44.79	43.52	75.99	44.00	16.50
8-11-89	73.48	18.30	73.55	42.00	20.00
8-9-90	78.50	13.30	81.30	46.00	20.75
8-12-91	74.18	15.30	77.50	47.25	16.50
8-12-92	87.62	10.96	79.20	50.00	16.00
8-11-93	74.23	21.50	84.35	51.50	14.75

D. September Forecasts, 1976-1993
(100 Million Bushels)

Date	PRDN _t	BGSTKS _t	USE _{t-1}	FEED _t	EXPTS _t
9-13-76	58.92	3.13	58.15	37.50	15.50
9-13-77	62.29	9.01	57.15	37.50	14.50
9-13-78	67.98	10.57	62.00	40.50	18.00
9-13-79	72.68	12.37	69.50	43.50	25.00
9-12-80	65.34	17.01	73.50	41.50	25.00
9-14-81	79.40	10.16	72.50	42.50	24.50
9-13-82	83.19	21.51	70.85	44.00	23.50
9-13-83	43.90	34.34	72.50	40.50	19.25
9-13-84	75.52	7.13	65.75	41.00	21.00
9-11-85	84.69	13.17	70.65	43.25	16.25
9-11-86	82.68	40.18	65.05	42.50	15.50
9-10-87	71.41	49.29	73.66	47.00	16.00
9-12-88	44.62	43.52	75.99	44.00	16.50
9-12-89	73.21	18.55	72.55	42.00	20.00
# 9-XX-90	81.18	13.30	81.30	47.00	20.75
9-12-91	72.95	15.30	77.50	47.25	16.50
9-10-92	87.70	10.81	79.35	50.00	15.50
9-9-93	72.29	21.50	84.35	51.00	14.00

#: Exact date not available.

E. October (Harvest) Forecasts, 1976-1993
(100 Million Bushels)

Date	PRDN _t	BGSTKS _t	USE _{t-1}	FEED _t	EXPTS _t
10-22-76	58.65	3.99	57.29	37.50	16.00
10-26-77	63.03	8.79	57.37	38.00	15.50
10-24-78	68.24	10.64	61.93	39.50	19.00
10-24-79	73.90	12.85	69.02	43.50	25.00
10-24-80	64.67	15.97	74.54	42.00	25.50
10-23-81	80.81	10.34	72.32	42.50	25.00
10-22-82	83.15	23.66	68.70	42.00	22.50
10-25-83	42.59	31.40	75.44	39.50	18.75
10-24-84	74.98	7.22	65.66	40.00	21.25
10-10-85	86.03	13.17	70.65	43.25	16.25
10-10-86	82.20	40.38	64.86	42.00	14.00
10-8-87	71.39	48.82	74.12	48.00	16.00
10-12-88	45.53	42.60	76.90	45.00	17.00
10-12-89	74.49	19.30	72.55	42.00	20.00
# 10-XX-90	79.35	13.34	81.15	47.00	20.75
10-10-91	74.79	15.21	77.60	48.00	16.50
10-8-92	89.38	11.00	79.15	51.50	15.50
10-12-93	69.62	21.13	84.73	50.50	14.00

#: Exact date not available.

Chapter 1: Introduction

10. Determine the correct calculation.
 - a. $5600 \times (9.6 \times 10^{-7}) = 5.376$ milli
 - b. $4.7\text{m}/1.2\mu = 4207$
 - c. $89.4\text{k} \times 1.2\text{m} = 97.28$
 - d. $5.6/17\text{m} = 32.9$
11. The correct expression for 8.54×10^{-5} is
 - a. 854 pico
 - b. 85.4
 - c. 85.4 micro
 - d. 85.5 kilo
12. Express 7.5×10^{-4} in milli, basic units, and micro.

a. 7.5 milli	0.075	75000 micro
b. 75 milli	0.075	7500 micro
c. 75 milli	0.0075	750 micro
d. 0.75 milli	0.00075	750 micro
13. Express these two calculator displays in correct metric units. 5.6-07 2.2 05
 - a. 56 micro 22 kilo
 - b. 0.56 micro 0.022 Meg
 - c. 0.56 micro 220 kilo
 - d. 56 micro 220 kilo
14. An electrical symbol for voltage is
 - a. I
 - b. V
 - c. C
 - d. R
15. A typical semiconductor device is
 - a. the transformer.
 - b. the diode.
 - c. the resistor.
 - d. the capacitor.
16. An electronic device that resists the flow of current in a circuit is known as
 - a. a capacitor
 - b. an inductor
 - c. a resistor
 - d. a transformer
17. An electronic device that stores electric charge is
 - a. a transformer
 - b. a capacitor
 - c. a resistor
 - d. an inductor
 - e. a semiconductor

Chapter 1: Introduction

18. A device that stores energy electromagnetically is
a. a capacitor
b. an inductor
c. a transistor
d. a diode
19. You have just calculated an answer for a problem. Your calculator reads 3.5-06. The correct metric value is
a. 35 milli
b. 35 micro
c. 3.5 Meg
d. 3.5 micro
e. 3.5 pico
20. Express 5.6×10^{-2} in milli, basic units, and micro.
- | | | |
|---------------|--------|-------|
| a. 5.6 milli | 0.056 | 56000 |
| b. 56 milli | 0.056 | 56000 |
| c. 560 milli | 5.6 00 | 5600 |
| d. 5600 milli | 56 | 560 |

Chapter 2: The Basic Electrical Quantities

1. The movement of free electrons along a conductor is called current.
 - a. true
 - b. false
2. Electrons attract each other.
 - a. true
 - b. false
3. A resistor color coded with bands of yellow, violet, and orange has a value of 4.7 k Ω .
 - a. true
 - b. false
4. A SPST switch is used to control one circuit.
 - a. true
 - b. false
5. To measure the current through a resistor, you place the ammeter so the current must pass through the meter.
 - a. true
 - b. false
6. The basic unit of resistance is the ohm.
 - a. true
 - b. false
7. A resistor color coded with bands of brown, black, and orange has a value of 10000 Ω .
 - a. true
 - b. false
8. A normally open push button switch could have current through it when not being pushed.
 - a. true
 - b. false
9. Electrons have a positive charge.
 - a. true
 - b. false
10. The opposition to the flow of current in a conductor is called resistance.
 - a. true
 - b. false
11. A material that has many free electrons is known as a/an
 - a. conductor.
 - b. insulator.
 - c. semiconductor.
 - d. poor conductor.

Chapter 2: The Basic Electrical Quantities

12. Opposition to the flow of current is called
 - a. voltage.
 - b. current.
 - c. capacitance.
 - d. resistance.
13. If you measure the current in a circuit and find it to be zero, it is probable that
 - a. the circuit has a short.
 - b. the power is turned off.
 - c. the resistance is very low.
 - d. the circuit voltage is very high.
14. A source, a path, and a load
 - a. make up a basic circuit.
 - b. can only be an open circuit.
 - c. will allow current to flow if the switch is open.
 - d. would be an incomplete circuit.
15. A definition of voltage is
 - a. the opposition to the flow of current.
 - b. the movement of free electrons.
 - c. the force that exists between charged particles.
 - d. the force that causes water to flow.
16. A unit of charge which contains 6.25×10^{18} electrons is known as
 - a. an ampere.
 - b. a joule.
 - c. a volt.
 - d. a coulomb.
17. A conductor is a material that has
 - a. few free electrons.
 - b. a positive charge.
 - c. many free electrons.
 - d. a structure similar to semiconductors.
18. A resistor has a value of $1.2 \Omega \pm 5\%$. It will be coded
 - a. Brown, black, red, gold.
 - b. Brown, black, silver, gold.
 - c. Brown, black, gold, silver.
 - d. Brown, red, gold, gold.
19. In figure 2-1, identify the DPST switch.
 - a. A
 - b. B
 - c. C
 - d. D
 - e. E

Chapter 2: The Basic Electrical Quantities

20. A resistor is color coded with yellow, violet, orange, and silver bands has a value and tolerance of
- 47 M Ω \pm 10%
 - 47 k Ω \pm 5%
 - 47 k Ω \pm 10%
 - 4.7 k Ω \pm 10%
21. A resistor is color coded with yellow, violet, orange, and gold bands has a value and tolerance of
- 47 M Ω \pm 10%
 - 47 k Ω \pm 5%
 - 47 k Ω \pm 10%
 - 4.7 k Ω \pm 10%
22. A resistor is color coded with bands of orange, orange, orange, and silver. The value and upper and lower tolerance limits are
- 33 k Ω , 32670--33330
 - 33 k Ω , 31350--34650
 - 33 k Ω , 29700--36300
 - 33 k Ω , 26400--39600
23. A resistor has a value of 100 k Ω \pm 10%. It will be coded
- black, brown, yellow, silver
 - brown, green, black, gold
 - brown, black, yellow, gold
 - brown, black, yellow, silver
24. See figure 2-2. The measured voltage V_{JK} is the same as
- V_{R5}
 - V_{R6}
 - V_{R7}
 - V_{R8}
25. See figure 2-2. The measured voltage V_{FG} is the same as
- V_{R6}
 - V_{R7}
 - V_{R8}
 - V_{R9}
26. See figure 2-2. Voltmeter leads placed across points C and D will read
- V_{R1}
 - V_{R2}
 - V_{R3}
 - V_{R4}
27. See figure 2-2. The measured voltage V_{CE} is the same as
- V_{R5}
 - $V_{R3} + V_{R4}$
 - $V_{R4} + V_{R5}$
 - V_{R6}

Chapter 2: The Basic Electrical Quantities

28. An analog ohmmeter should
- a. be connected across a circuit with the power on.
 - b. be inserted into the circuit so the current flows through it.
 - c. placed across the resistance after the resistance is opened.
 - d. have the polarity carefully checked before its use.
29. Most DMM's will measure _____, _____, and _____.
- a. frequency, voltage, current
 - b. voltage, current, capacitance
 - c. voltage, frequency, resistance
 - d. voltage, current, resistance

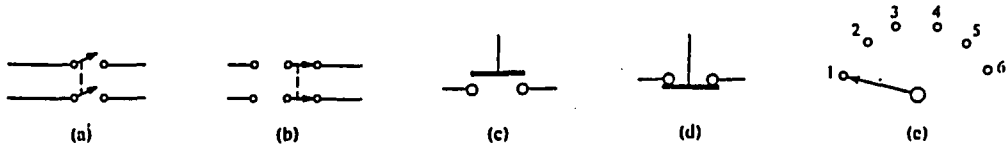


Figure 2-1

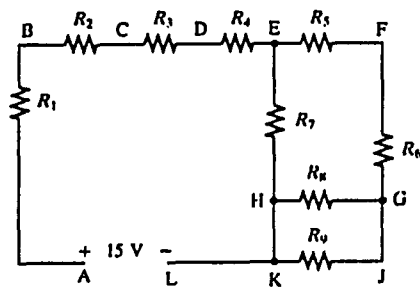


Figure 2-2

CHAPTER 1 QUIZ

Student Name _____

1. Georg Simon Ohm developed Ohm's law around 1820.
 - a. true
 - b. false
2. Many careers exist for the electronic technician.
 - a. true
 - b. false
3. The unit of current is the ampere.
 - a. true
 - b. false
4. 15,000 V can be expressed in powers of ten as 15×10^3 V.
 - a. true
 - b. false
5. 0.0015 A can be expressed in metric units as 1.5 mA.
 - a. true
 - b. false
6. Some typical careers for electronic technicians are
 - a. technical writers
 - b. technical salespersons
 - c. manufacturing technicians
 - d. service shop technicians
 - e. all of the above
7. A circuit component that resists the flow of current in a circuit is known as
 - a. a capacitor
 - b. an inductor
 - c. a resistor
 - d. a transformer
8. A circuit component that stores electric charge is
 - a. a transformer
 - b. a capacitor
 - c. a resistor
 - d. an inductor
 - e. a semiconductor

9. Some semiconductor devices are
- transformers, transistors, and integrated circuits.
 - diodes, transistors, and resistors.
 - integrated circuits, inductors, and capacitors.
 - integrated circuits, capacitors, and diodes.
 - diodes, transistors, and integrated circuits.
10. The electrical symbol for capacitance is
- I
 - V
 - C
 - Q
 - E
11. The symbol A is an abbreviation for
- farad
 - volt
 - hertz
 - henry
 - ampere
12. A device that stores energy electromagnetically is
- a capacitor
 - an inductor
 - a transistor
 - a diode
13. The symbol and unit for time is
- t, I
 - C, f
 - t, s
 - Z, W
14. The value $4.7 \times 10^3 \Omega$ can be expressed as
- 0.00047 Ω
 - 4.7 k Ω
 - 4.7 Ω
 - 4.7 M Ω
15. You have just calculated an answer for a problem. Your calculator reads 3.5-06. The correct metric value is
- 35 milli-
 - 35 micro-
 - 3.5 mega-
 - 3.5 micro-
 - 3.5 pico-

16. You are trying to enter 45,600 Ω into your calculator. A correct entry might be
- 4.56 03
 - 4.56-03
 - 456 01
 - 4.56 04
 - 45.6 05
17. Your calculator gives you an answer on its display of 1.2 05. A correct metric value of resistance for this answer is
- 12 $k\Omega$
 - 0.12 $M\Omega$
 - 12,000 Ω
 - 1200 Ω
18. The correct expression for 7.84×10^{-4} F is
- 784 pF
 - 0.0784 μF
 - 7.84 μF
 - 7840 μF
19. Express these calculator displays in correct metric values: 4.7-06, 1.5 04, 9.5-03.
- | | | | |
|----|------------|----------|--------------|
| a. | 47 milli- | 15000 | 9.5 milli- |
| b. | 470 | 1500 | 0.095 micro- |
| c. | 4.7 micro- | 15 kilo- | 9.5 milli- |
| d. | 470 milli- | 15 kilo- | 9.5 milli- |
20. Express 5.6×10^{-2} in milli-, basic units, and micro-.
- | | | | |
|----|------|-------|-------|
| a. | 5.6 | 0.056 | 56000 |
| b. | 56 | 0.056 | 56000 |
| c. | 560 | 5.6 | 5600 |
| d. | 5600 | 56 | 560 |

CHAPTER 2 QUIZ

Student Name _____

1. The movement of free electrons along a conductor is called voltage.
 - a. true
 - b. false
2. Electrons repel each other.
 - a. true
 - b. false
3. A resistor color coded with bands of red, red, orange has a value of 2.2 k Ω .
 - a. true
 - b. false
4. Generally, digital meters are not as accurate as analog meters.
 - a. true
 - b. false
5. To measure the current through a resistor, you place the ammeter across the resistor.
 - a. true
 - b. false
6. A conductor is a material that has
 - a. few free electrons.
 - b. a positive charge.
 - c. many free electrons.
 - d. a structure similar to semiconductors.
7. A material with few free electrons is known as
 - a. a conductor.
 - b. an insulator.
 - c. a semiconductor.
8. A resistor color coded with yellow, violet, red, and silver bands has a value and tolerance of
 - a. 47 M Ω +/- 10%
 - b. 4.7 k Ω +/- 5%
 - c. 4700 Ω +/- 5%
 - d. 0.0047 M Ω +/- 10%

9. A resistor has a value of $1.2 \Omega \pm 5\%$. It will be coded
- brown, black, red, gold.
 - brown, black, silver, gold.
 - brown, black, gold, silver.
 - brown, red, gold, gold.
10. A definition of resistance is
- the ability to store a charge.
 - the opposition to the flow of current.
 - the movement of free electrons.
 - the potential difference across a source.

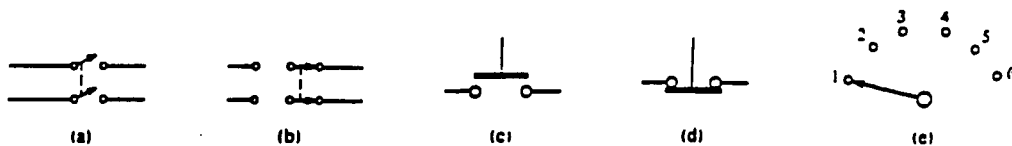


FIGURE 2-1

11. In Figure 2-1, identify the DPST switch.
- A
 - B
 - C
 - D
 - E
12. In Figure 2-1, identify the normally closed push button switch.
- A
 - B
 - C
 - D
 - E
13. In Figure 2-1, identify the DPDT switch.
- A
 - B
 - C
 - D
 - E
14. A complete basic electrical circuit consists of
- a source, a load, and a resistor.
 - a battery, a resistor, and a capacitor.
 - a source, a load, and a path.
 - a battery, a path, and a switch.

15. In order to measure the current in a circuit, the ammeter
- must be placed across the load.
 - must be placed so the current must pass through the meter.
 - must be placed across the source.
 - should not be used. A voltmeter is the correct instrument.
16. The most common type of diagram used in electronic work is
- a pictorial diagram.
 - a wiring diagram.
 - a schematic diagram.
 - a three-view diagram.

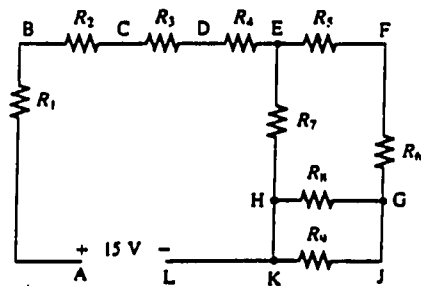


FIGURE 2-2

17. See Figure 2-2. If you place the red lead of a voltmeter on point F and the black lead on point G, you will read
- V_{R5}
 - I_{R5}
 - V_{R8}
 - V_{R9}
18. See Figure 2-2. To measure the current through R_8 , the circuit must be opened and the meter placed at point
- A
 - E
 - J
 - H

19. See Figure 2-2. Voltmeter leads placed across points E and G will read

- a. V_{R3}
- b. V_{R4}
- c. $V_{R7} + V_{R3}$
- d. V_{R7}

20. See Figure 2-2. The measured voltage V_{HG} is the same as

- a. V_{R7}
- b. V_{R3}
- c. V_{R5}
- d. V_{R3}

APPENDIX D: POSTTESTS (HOMEWORK)

Chapter 3: Ohm's Law and Power

1. If the current is constant then voltage and resistance are directly proportional.
a. true
b. false
2. A circuit has a supply voltage of 15 V. The resistance is 4700 Ω . The current is 313 mA.
a. true
b. false
3. A 1 k Ω resistor has 32 mA flowing through it. The resistor is dissipating 1.024 W.
a. true
b. false
4. If the resistance in a circuit increases, then the current will decrease.
a. true
b. false
5. A 47 k Ω resistor has 5 mA flowing through it. It is OK to use a resistor with a power rating of 1 W.
a. true
b. false
6. A circuit has a supply voltage of 20 V and a resistance of 3300 Ω . The current is 6.06 mA.
a. true
b. false
7. A 2.5 k Ω resistor has 45 mA flowing through it. The resistor is dissipating 112.5 W.
a. true
b. false
8. If the resistance in a circuit decreases, then the current will also decrease.
a. true
b. false
9. A 56 k Ω resistor has 10 mA flowing through it. It is OK to use a resistor with a power rating of 10 W.
a. true
b. false
10. A circuit has a resistor of 12 k Ω with a current of 12 mA flowing through it. The circuit voltage is 1 V.
a. true
b. false

Chapter 3: Ohm's Law and Power

11. Voltage and current are
 - a. directly proportional.
 - b. inversely proportional.
 - c. not related.
 - d. quantities that add.
12. If the voltage across a circuit increases, then
 - a. the current decreases.
 - b. the resistance increases.
 - c. the resistance decreases.
 - d. the current increases.

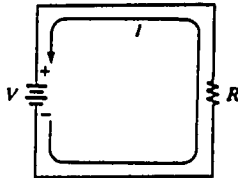


Figure 3-1

13. See figure 3-1. If $V = 25 \text{ V}$, and $R = 50 \text{ k}\Omega$, the current would equal
 - a. 50 mA
 - b. 5 mA
 - c. .5 mA
 - d. 2 mA
14. See figure 3-1. If $I = 64 \text{ mA}$, and $R = 470 \Omega$, the voltage would equal
 - a. 30.08 V
 - b. 3.008 V
 - c. 73.43 V
 - d. 7.343 V
15. See figure 3-1. If $V = 72 \text{ V}$, and $I = 12 \text{ mA}$, the resistance would equal
 - a. 0.166 Ω
 - b. 6 k Ω
 - c. 864 Ω
 - d. 47 k Ω
16. See figure 3-1. $V = 12 \text{ V}$ and $R = 12 \text{ k}\Omega$ If the resistor shorts, the current will be
 - a. 1 mA
 - b. 10 mA
 - c. 0 mA
 - d. extremely large

Chapter 3: Ohm's Law and Power

17. See figure 3-1. If the voltage were suddenly switched off,
 - a. the current will be zero.
 - b. the current will gradually decrease to zero.
 - c. the current will first increase and then decrease to zero.
 - d. there is no way to predict the current.
18. See figure 3-1. If $V = 100\text{ V}$ and $I = 1\text{ mA}$, then the power dissipated by the resistor is
 - a. 10 W
 - b. 1 W
 - c. 100 mW
 - d. 10 mW
19. A circuit consists of a resistor color coded yellow, violet, orange, and gold. This resistor is placed across a source of 15 V. What value of resistor and wattage rating could be used?
 - a. 4.7 k Ω at 1/8 W
 - b. 47 k Ω at 1/4 W
 - c. 4700 Ω at 1/4 W
 - d. 0.47 M Ω at 1/4 W
20. A 220 Ω , 1/2 W resistor has burned and is open. You look in your parts box and find the following resistors. Which resistor could you use to repair the circuit?
 - a. 2200 Ω , 1/2 W
 - b. 220 Ω , 1/4 W
 - c. 220 Ω , 1/8 W
 - d. 220 Ω , 1 W
21. See figure 3-1. If the resistor opens,
 - a. the power dissipated will decrease.
 - b. the current will increase.
 - c. the resistance will decrease.
 - d. the voltage will increase.
22. A 100 watt light bulb has a resistance measurement of 56 Ω when out of the circuit. What is the resistance of the bulb when it is on and in a circuit with a supply of 120 V?
 - a. 56 Ω
 - b. 2.14 Ω
 - c. 144 Ω
 - d. 560 Ω
23. A rating of 1/2 W for a resistor means that the resistor
 - a. can safely dissipate 1/2 W of power.
 - b. always dissipates 1/2 W.
 - c. always provides 1/2 W of power.
 - d. can only dissipate more than 1/2 W of power.

Chapter 3: Ohm's Law and Power

24. Which is the correct formula for Ohm's Law?
- $V = I/R$
 - $R = VI$
 - $I = V/R$
 - $P = VI$
25. A resistor color coded yellow, violet, brown, and gold is connected to a 12 V source. If the resistor is within tolerance, what is the maximum current that will flow?
- 24.3 mA
 - 25.5 mA
 - 26.9 mA
 - 255 mA
26. Resistance and current are
- directly proportional.
 - inversely proportional.
 - not related.
 - are similar to voltage.
27. See figure 3-1. If $I = 32 \text{ mA}$, and $R = 469 \Omega$ then $V =$
- 12 V
 - 15 V
 - 19 V
 - 22 V
28. Which of the following terms is not a resistor rating.
- resistor value in ohms
 - resistor tolerance.
 - current
 - power rating
29. See figure 3-1. $V = 12 \text{ V}$ and R is color coded brown, black, orange. You measure the current in the circuit. What limits of current might you expect to measure?
- 1.2 mA and 1.4 mA
 - 1 mA and 1.6 mA
 - 0.8 mA and 1.2 mA
 - 1 ma and 1.5 ma
30. See figure 3-1. If the resistor develops an open,
- the power dissipated will increase.
 - the circuit current will decrease.
 - the source voltage will decrease to zero.
 - the resistance will decrease.
31. A current of $250 \mu\text{A}$ through a $4.7 \text{ k}\Omega$ resistor produces a voltage drop of
- 53.2 V
 - 1.175 mV
 - 18.8 V
 - 1.175 V

Chapter 3: Ohm's Law and Power

32. A resistance of $2.2\text{ M}\Omega$ is connected across a 1 kV source. The resulting current is approximately
- a. 2.2 mA
 - b. 0.455 mA
 - c. $45.5\text{ }\mu\text{A}$
 - d. 0.455 A
33. A $2.2\text{ k}\Omega$ resistor dissipates 0.5 W . The current is
- a. 15.1 mA
 - b. 0.227 mA
 - c. 1.1 mA
 - d. 4.4 mA
34. A $330\text{ }\Omega$ resistor dissipates 2 W . The voltage is
- a. 2.57 V
 - b. 660 V
 - c. 6.6 V
 - d. 25.7 V
35. The power rating of a carbon-composition resistor that is to handle up to 1.1 W should be
- a. 0.25 W
 - b. 1 W
 - c. 2 W
 - d. 5 W

Chapter 4: Series Circuits

1. In a series circuit, the current is the same everywhere in the circuit.
a. true
b. false
2. Kirchoff's Voltage Law states that the product of the individual voltage drops equals the source voltage.
a. true
b. false
3. The total power dissipated in a series circuit is the sum of the individual powers.
a. true
b. false
4. Three resistors, 6.8 k Ω , 1.2 k Ω , and 5.6 k Ω are in series. The total resistance is 13.6 k Ω .
a. true
b. false
5. A resistor is dissipating 1/4 W. This means that it can supply 1/4 W to the load.
a. true
b. false
6. Three resistors, 4.7 k Ω , 2.2 k Ω , and 1.2 k Ω are in series. The total resistance is 8.7 k Ω .
a. true
b. false
7. The total power dissipated in a series circuit is equal to the source voltage multiplied by the current.
a. true
b. false
8. A resistor is rated at 1/2 W. This resistor can safely dissipate 0.325 W.
a. true
b. false
9. The sum of the individual voltage drops in a series circuit equals the source voltage. This statement is Kirchhoff's Law.
a. true
b. false
10. Two resistors are in series. One is a 1/4 W resistor and the other is a 1/2 W resistor. This circuit can safely dissipate 1 3/4 W.
a. true
b. false

Chapter 4: Series Circuits

11. See figure 4-1. $R_1 = 10\text{ k}\Omega$, $R_2 = 10\text{ k}\Omega$ and $R_3 = 15\text{ k}\Omega$. What is the total resistance, R_T ?
- 25 $\text{k}\Omega$
 - 35 $\text{k}\Omega$
 - 0 Ω
 - infinite Ω

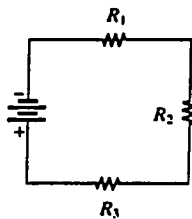


Figure 4-1

12. See figure 4-1. $R_1 = 10\text{ k}\Omega$, $V_{R1} = 16\text{ V}$, $R_2 = 10\text{ k}\Omega$, $R_3 = 15\text{ k}\Omega$. Calculate the current in the circuit.
- 3.2 mA
 - 1.6 mA
 - 0
 - 12 mA
13. See figure 4-1. $R_1 = 10\text{ k}\Omega$, $V_{R1} = 16\text{ V}$, $R_2 = 10\text{ k}\Omega$, $R_3 = 15\text{ k}\Omega$. Calculate the voltage drops across R_2 and R_3 .
- $V_{R2} = 16\text{ V}$ $V_{R3} = 12\text{ V}$
 - $V_{R2} = 16\text{ V}$ $V_{R3} = 24\text{ V}$
 - $V_{R2} = 16\text{ V}$ $V_{R3} = 16\text{ V}$
 - $V_{R2} = 24\text{ V}$ $V_{R3} = 12\text{ V}$
14. See figure 4-1. $R_1 = 10\text{ k}\Omega$, $V_{R1} = 16\text{ V}$, $R_2 = 10\text{ k}\Omega$, $R_3 = 15\text{ k}\Omega$. The power dissipated in R_2 is
- 25.6 mW
 - 2.56 mW
 - .256 mW
 - .0256 mW
15. See figure 4-1. $R_1 = 10\text{ k}\Omega$, $V_{R1} = 16\text{ V}$, $R_2 = 10\text{ k}\Omega$, $R_3 = 15\text{ k}\Omega$. The supply voltage V_S is
- 16 V
 - 24 V
 - 56 V
 - 112 V

Chapter 4: Series Circuits

16. See figure 4-1. $R_1 = 10 \text{ k}\Omega$, $V_{R1} = 16 \text{ V}$, $R_2 = 10 \text{ k}\Omega$, $R_3 = 15 \text{ k}\Omega$
The total circuit resistance if R_2 opens is
 - a. $25 \text{ k}\Omega$
 - b. $10 \text{ k}\Omega$
 - c. 0Ω
 - d. infinite Ω
17. See figure 4-1. If R_2 opens, the total power dissipated by the circuit will
 - a. increase
 - b. decrease
 - c. remain the same
 - d. will be dependent upon the source voltage.
18. Two power supplies are in series with voltages of 16 V and -12 V , respectively. What is the total supply voltage?
 - a. 28 V
 - b. -4 V
 - c. -28 V
 - d. 4 V
19. Two sources, 12 V and -19 V are connected so the total voltage is -7 V . These sources are said to be
 - a. series aiding.
 - b. series opposing.
 - c. in parallel.
 - d. dangerous to connect.
20. Three $47 \text{ k}\Omega$ resistors are connected in series across a 100 V source. Find P_T .
 - a. 70.9 mW
 - b. 23.6 mW
 - c. 22 W
 - d. 709 mW
21. Three resistors are connected in series across a 50 V source. The voltage drop across one of the resistors is 19.7 V and the drop across the another is 2.7 V . What is the drop across the third resistor?
 - a. 30.3 V
 - b. 47.3 V
 - c. 22.4 V
 - d. 27.6 V
22. The polarity of voltages across a resistor is dependent on the current direction. The resistor end where current enters is said to be _____, and the other end is _____.
 - a. positive, positive
 - b. negative, negative
 - c. negative, positive
 - d. positive, negative

Chapter 4: Series Circuits

23. A series circuit with four resistors connected across a 50 V source, has a current of 100 μA flowing through it. The values for three of the resistors are 12 k Ω , 47 k Ω , and 56 k Ω . What is the value of the fourth resistor?
- 38.5 k Ω
 - 3.85 k Ω
 - 385 k Ω
 - 3.85 M Ω
24. Two resistors are in series. $R_1 = 12 \text{ k}\Omega$ and $R_2 = 5 \text{ k}\Omega$. A source voltage of 20 V is applied. V_{R1} will be _____, and V_{R2} will be _____.
- 5.88 V, 14.12 V
 - 14.12 V, 5.88 V
 - 10 V, 10 V
 - 0 V, 20 V
25. Four resistors are connected in series across a source of 18 V. You measure the voltage across each resistor and find the voltage to be 0 V across three of them but 18 V across the last. What is the problem?
- Two of the resistors are shorted
 - The three resistors are open.
 - One resistor is open.
 - No problem, this is normal.
26. Two power supplies are in series with voltages of 12 V and 17 V respectively. What is the total supply voltage?
- 5 V
 - 5 V
 - 29 V
 - 29 V
27. Two resistors are in series across a source of 20 volts. Each resistor has a value of 100 k Ω . What is the voltage across each resistor?
- 20 V
 - 10 V
 - 100 mA
 - 100 k Ω
28. A two-resistor voltage divider has $R_1 = 22 \text{ k}\Omega$ and $R_2 = 12 \text{ k}\Omega$ is connected across 47 volts. What is the voltage across R_2 ?
- about 16.6 V
 - about 30.4 V
 - about 25.6 V
 - about 17.2 V

Chapter 4: Series Circuits

29. A 500 k Ω potentiometer is connected across 5 V. The voltage from the wiper to the lower end of the pot is 1.2 V. What is the resistance of the lower part of the potentiometer?
- 380 k Ω
 - 120 k Ω
 - 500 k Ω
 - 0 Ω
30. Three batteries are in series with potentials of -1.2 V, 5 V, and 6 V. The total supply voltage is
- 12.2 V
 - 9.8 V
 - 1.2 V
 - 1.3 V
31. A series circuit consists of three resistors with values of 100 Ω , 220 Ω , and 330 Ω . The total resistance is
- less, than 100 Ω
 - the average of the values
 - 650 Ω
 - 1650 Ω
32. A 9 V battery is connected across a series combination of 68 Ω , 33 Ω , 100 Ω , and 47 Ω resistors. The amount of current is
- 36.3 mA
 - 27.56 A
 - 22.32 mA
 - 326.6 mA
33. There are six resistors in a given series circuit and each resistor has 5 V dropped across it. The source voltage is
- 5 V
 - 30 V
 - dependent on the resistor values
 - dependent on the current
34. A series circuit consists of a 4.7 k Ω , a 5.6 k Ω , and a 10 k Ω resistor. The resistor that has the most voltage across it is
- the 4.7 k Ω
 - the 5.6 k Ω
 - the 10 k Ω
 - impossible to determine from the given information
35. The total power in a certain circuit is 10 W. Each of the five equal-value series resistors making up the circuit dissipates
- 10 W
 - 50 W
 - 5 W
 - 2 W

Chapter 5: Parallel Circuits

1. Three equal resistors are connected in parallel. The source voltage is 12 V. The voltage across each resistor is 4 V.
a. true
b. false
2. The total resistance of four resistors in parallel is always less than the smallest resistor.
a. true
b. false
3. A parallel branch has 0.065 mA flowing and the other branch has 0.098 mA flowing. The total current is 0.163 mA.
a. true
b. false
4. If one branch of a parallel circuit opens, the total resistance will decrease.
a. true
b. false
5. The total power dissipation of resistors in parallel can be found by adding the individual powers.
a. true
b. false
6. Three equal resistors are connected in parallel. The source voltage is 18 V. The voltage across each resistor is 6 V.
a. true
b. false
7. The total resistance of three resistors in parallel is the sum of the individual resistor values.
a. true
b. false
8. A parallel branch has a current of 75 mA and another branch has a current of 12.7 mA. The total current is 85.7 mA.
a. true
b. false
9. If one branch of a parallel circuit shorts, the total resistance will decrease.
a. true
b. false
10. Two resistors are in parallel. One is dissipating 0.25 W and the other is dissipating 1.2 W. The total power dissipated is 1.25 W.
a. true
b. false

Chapter 5: Parallel Circuits

11. Three resistors are connected in parallel. The values are 5.5 k Ω , 22 k Ω , and 500 Ω . What is R_T ?
 - a. 28.1 k Ω
 - b. 27.6 k Ω
 - c. 450 Ω
 - d. 330 Ω
12. Three resistors, 500 Ω , 1200 Ω , and 10 k Ω , are connected in parallel across 25 V. What is the current through the 1200 Ω resistor?
 - a. 20.83 mA
 - b. 50 mA
 - c. 2.5 mA
 - d. 2.4 mA
13. Two resistors are in parallel, 2.2 k Ω and 3.3 k Ω . The total resistance of the circuit is
 - a. 2.2 k Ω
 - b. 3.3 k Ω
 - c. greater than 2.2 k Ω
 - d. less than 2.2 k Ω
14. A parallel circuit consists of $R_1 = 0.22$ M Ω , $R_2 = 1$ M Ω , and R_3 . If $R_T = 0.1166$ M Ω , find R_3 .
 - a. 1.34 M Ω
 - b. 0.33 M Ω
 - c. 0.134 M Ω
 - d. 13,400 Ω
15. Three resistors are connected in parallel across 18 V. The values are 1 M Ω , 0.470 M Ω , and 0.5 M Ω . If the 1 M Ω resistor opens, the total current will be
 - a. 74.3 μ A.
 - b. 74.3 mA.
 - c. 92.3 μ A.
 - d. 92.3 mA.
16. Twelve 1.5 M Ω resistors are connected in parallel across 50 V. What is R_T ?
 - a. 1.5 M Ω
 - b. 1.25 M Ω
 - c. 1 M Ω
 - d. 0.125 M Ω
17. A parallel circuit with three resistors in parallel has a total current of 0.1 mA. If $I_1 = 0.022$ mA and $I_2 = 0.007$ mA, what is the current through the third resistor, I_3 ?
 - a. 0.029 mA
 - b. 0.071 mA
 - c. 0.142 mA
 - d. 0.213 mA

Chapter 5: Parallel Circuits

18. Four resistors are connected in parallel. If one resistor opens, the total resistance will and the total current will
 - a. decrease, increase
 - b. increase, increase
 - c. decrease, decrease
 - d. increase, decrease
19. Three 22 k Ω resistors are connected in parallel across a 10 V source. P_T equals
 - a. 4.5 mW.
 - b. 13.6 mW.
 - c. 18.1 mW.
 - d. 22.6 mW.
20. If a resistor in parallel shorts, the total current will
 - a. equal 0.
 - b. increase.
 - c. decrease.
 - d. decrease, then increase to 0.
21. Four 100 W lamps are connected in parallel across 120 V. What is the total current to the circuit?
 - a. 3.33 A
 - b. 833 mA
 - c. 33.3 A
 - d. 8.33 A
22. You have a circuit with four resistors in parallel. You measure the total current and find that it is lower than normal. Which statement best describes a possible trouble?
 - a. One of the resistors shorted.
 - b. The power supply is off.
 - c. All of the resistors opened.
 - d. One resistor opened.
23. A correct formula concerning a parallel circuit with two branches is
 - a. $R_T = R_1 + R_2$
 - b. $V_T = V_1 + V_2$
 - c. $I_T = I_1 + I_2$
 - d. $R_T = V_1/I_2$
24. The current through any branch of a parallel circuit is
 - a. dependent on the power rating of the resistor.
 - b. only dependent on the circuit voltage.
 - c. directly proportional to the branch resistance.
 - d. inversely proportional to the branch resistance.

Chapter 5: Parallel Circuits

25. If you want to measure a voltage across a load with a DVM, the meter is connected
- in series with the load.
 - across the source.
 - in parallel with the load.
 - in series with the source.
26. A parallel circuit consisting of $R_1 = 100\ \Omega$, $R_2 = 500\ \Omega$ and R_3 has an $R_T = 76.92\ \Omega$. Find the value of R_3 .
- $140\ \Omega$
 - $1000\ \Omega$
 - $1850\ \Omega$
 - Cannot compute; not enough data.
27. A parallel circuit consists of $R_1 = 1200\ \Omega$ in parallel with R_2 . $I_T = 0.005\ \text{mA}$, $I_2 = 0.003\ \text{mA}$. What is the value of V_{R_1} ?
- $6\ \text{mV}$
 - $18\ \text{mV}$
 - $3.6\ \text{mV}$
 - $2.4\ \text{mV}$
28. As resistors are added in parallel to a circuit,
- I_T decreases and R_T increases.
 - I_T decreases and R_T decreases.
 - I_T increases and R_T decreases.
 - I_T increases and R_T increases.
29. A circuit consists of three resistors in parallel, $R_1 = 4.7\ \text{k}\Omega$, $R_2 = 3.3\ \text{k}\Omega$, and $R_3 = 5.43\ \text{k}\Omega$. $I_T = 35\ \text{mA}$ and $V_S = 50\ \text{V}$. Find I_{R_3} .
- $10.64\ \text{mA}$
 - $15.15\ \text{mA}$
 - $9.21\ \text{mA}$
 - $4.72\ \text{mA}$
30. Two resistors are in parallel. $R_1 = 470\ \Omega$ and $R_T = 330\ \Omega$. Find the value of R_2 .
- $770\ \Omega$
 - $1108\ \Omega$
 - $194\ \Omega$
 - $110\ \Omega$
31. A $330\ \Omega$ resistor, a $270\ \Omega$ resistor and a $68\ \Omega$ resistor are all in parallel. The total resistance is approximately
- $668\ \Omega$
 - $47\ \Omega$
 - $68\ \Omega$
 - $22\ \Omega$

Chapter 5: Parallel Circuits

32. The currents into a junction flow along two paths. One current is 5 A and the other is 3 A. The total current out of the junction is
- a. 2 A
 - b. unknown
 - c. 8 A
 - d. the larger of the two
33. In a four-branch parallel circuit, there is 10 mA of current in each branch. If one of the branches opens, the current in each of the other three branches is
- a. 13.33 mA
 - b. 10 mA
 - c. 0 A
 - d. 30 mA
34. If there is a total of 100 mA into a parallel circuit consisting of three branches and two of the branch currents are 40 mA and 20 mA, the third branch current is
- a. 60 mA
 - b. 20 mA
 - c. 160 mA
 - d. 40 mA
35. The power dissipation in each of four parallel branches is 1 W. The total power dissipation is
- a. 1 W
 - b. 4 W
 - c. 0.25 W

Chapter 6: Series-Parallel Circuits

1. See figure 6-1. R_2 is in parallel with R_3 .
 - a. true
 - b. false
2. See figure 6-1. R_1 is in series with R_3 .
 - a. true
 - b. false
3. See figure 6-1. R_1 is in series with the parallel combination R_2 and R_3 .
 - a. true
 - b. false
4. Resistors are in parallel if they share the same voltage.
 - a. true
 - b. false
5. A combination circuit consists of resistors in both series and parallel.
 - a. true
 - b. false
6. See figure 6-1. R_1 is in series with the series combination R_2 and R_3 .
 - a. true
 - b. false
7. No problems could occur if a voltage source of 10 V were to be connected in parallel with a 20 V source.
 - a. true
 - b. false
8. A loaded voltage divider is a combination circuit.
 - a. true
 - b. false
9. Two or more resistors connected in series form a circuit known as a voltage divider.
 - a. true
 - b. false
10. Resistors are in parallel if they share the same current.
 - a. true
 - b. false

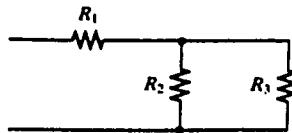
Chapter 6: Series-Parallel Circuits

Figure 6-1

11. See figure 6-1. Resistor R_2 is connected
- in series with R_1 .
 - in series with R_3 .
 - in parallel with R_1 .
 - in parallel with R_3 .

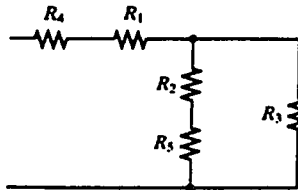


Figure 6-2

12. See figure 6-2. R_2 and R_5 are connected
- in series with each other and R_3 .
 - in series with each other and R_1 and R_4 .
 - in series.
 - in parallel with R_3 .
13. See figure 6-2. If all of the resistors are $4.7\text{ k}\Omega$, find R_T .
- $12.53\text{ k}\Omega$
 - $18.8\text{ k}\Omega$
 - $9.4\text{ k}\Omega$
 - $4.7\text{ k}\Omega$
14. See figure 6-2. R_1 , R_2 , and R_3 each equal $10\text{ k}\Omega$. R_4 and R_5 each equal $50\text{ k}\Omega$. Find R_T .
- $8.57\text{ k}\Omega$
 - $130\text{ k}\Omega$
 - $68.57\text{ k}\Omega$
 - $85.7\text{ k}\Omega$

Chapter 6: Series-Parallel Circuits

15. See figure 6-2. If all the resistors are $4.7\text{ k}\Omega$, and source voltage is 20 V , find I_{R2} .
- 12.53 mA
 - 0.53 mA
 - 11.99 mA
 - 1.06 mA
16. See figure 6-1. If R_3 opens, V_{R1} will
- increase
 - decrease
 - remain the same
 - decrease to zero.
17. See figure 6-2. If R_1 opens, V_{R2} will
- increase
 - decrease
 - remain the same
 - cause the fuse to blow
18. See figure 6-2. If R_5 shorts, V_{R2} will
- increase
 - decrease
 - remain the same
 - decrease to zero

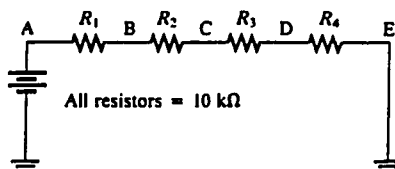


Figure 6-3

19. See figure 6-3. The resistance between points B and E
- $10\text{ k}\Omega$
 - $20\text{ k}\Omega$
 - $30\text{ k}\Omega$
 - $40\text{ k}\Omega$
20. See figure 6-3. If $V_4 = 10\text{ V}$, find V_{AD} .
- 10 V
 - 20 V
 - 30 V
 - 40 V

Chapter 6: Series-Parallel Circuits

21. See figure 6-3. If $V_S = 22\text{ V}$, find V_{DB} .
 - a. 5.5 V
 - b. 22 V
 - c. 16.5 V
 - d. -11.5 V
22. See figure 6-3. If $V_S = 12\text{ V}$ and R_3 shorts, find V_{EB} .
 - a. -3 V
 - b. -8 V
 - c. 6 V
 - d. 8 V
23. See figure 6-3. If another 10 k Ω resistor were placed in parallel with R_4 , V_{R4} will
 - a. increase
 - b. decrease
 - c. remain the same
 - d. change to 4 volts
24. See figure 6-1. $V_S = 20\text{ V}$, $R_1 = 10\text{ k}\Omega$, $R_2 = 50\text{ k}\Omega$, and $R_3 = 15\text{ k}\Omega$. Find P_2 .
 - a. 2.29 mW
 - b. 7.64 mW
 - c. 8.63 mW
 - d. 18.6 mW
25. See figure 6-2. If R_3 shorts, V_{R5} will
 - a. increase
 - b. decrease
 - c. remain the same
 - d. equal V_{R1}
26. See figure 6-1. Resistor R_1 is connected
 - a. in series with R_2 .
 - b. in series with R_3 .
 - c. in parallel with R_2 .
 - d. in parallel with R_3 .
 - e. none of these
27. See figure 6-2. R_2 and R_5 are connected
 - a. in series with each other and in parallel with R_3 .
 - b. in parallel.
 - c. in series with R_1 .
 - d. in series with R_3 .
28. See figure 6-1. If $R_1 = 4.7\text{ k}\Omega$, $R_2 = 3300\text{ }\Omega$ and $R_3 = 1000\text{ }\Omega$, the total resistance of the circuit is
 - a. 5700 Ω
 - b. 5467 Ω
 - c. 4125 Ω
 - d. 660 Ω

Chapter 6: Series-Parallel Circuits

29. See figure 6-1. If $R_1 = 4.7 \text{ k}\Omega$, $R_2 = 3300 \text{ }\Omega$, $R_3 = 1000 \text{ }\Omega$, and the source voltage is 50 V, calculate the total current.
- 8.8 mA
 - 9.15 mA
 - 12.1 mA
 - 75.7 mA
30. If a combination of four parallel $10 \text{ k}\Omega$ resistors were in series with a single $20 \text{ k}\Omega$ resistor, and one of the parallel combination resistors opened, the voltage across the other parallel resistors would
- increase.
 - decrease.
 - remain the same.
31. Two $1 \text{ k}\Omega$ resistors are in series and this series combination is in parallel with a $2.2 \text{ k}\Omega$ resistor. The voltage across one of the $1 \text{ k}\Omega$ resistors is 6 V. The voltage across the $2.2 \text{ k}\Omega$ resistor is
- 6 V
 - 3 V
 - 12 V
 - 13.2 V
32. The parallel combination of a $330 \text{ }\Omega$ resistor and a $470 \text{ }\Omega$ resistor is in series with the parallel combination of four $1 \text{ k}\Omega$ resistors. A 100 V source is connected across the circuit. The resistor with the most current has a value of
- $1 \text{ k}\Omega$
 - $330 \text{ }\Omega$
 - $470 \text{ }\Omega$
33. The parallel combination of a $330 \text{ }\Omega$ resistor and a $470 \text{ }\Omega$ resistor is in series with the parallel combination of four $1 \text{ k}\Omega$ resistors. A 100 V source is connected across the circuit. The resistor with the most voltage across it has a value of
- $1 \text{ k}\Omega$
 - $330 \text{ }\Omega$
 - $470 \text{ }\Omega$
34. A certain voltage divider consists of two $10 \text{ k}\Omega$ resistors in series. Which of the following load resistors will have the most effect on the output voltage?
- $1 \text{ M}\Omega$
 - $20 \text{ k}\Omega$
 - $100 \text{ k}\Omega$
 - $10 \text{ k}\Omega$

Chapter 6: Series-Parallel Circuits

35. In a certain two-source circuit, one source acting alone produces 10 mA through a given branch. The other source acting alone produces 8 mA in the opposite direction through the same branch. The total current through the branch is
- a. 10 mA
 - b. 8 mA
 - c. 18 mA
 - d. 2 mA

Chapter 8: Introduction to Alternating Current and Voltage.

1. The frequency of a sine wave is the reciprocal of the period.
a. true
b. false
2. The higher the frequency of a sine wave, the shorter the period.
a. true
b. false
3. The peak value of a sine wave is smaller than the rms value.
a. true
b. false
4. If an ac voltage is applied to a resistor, the current is inversely proportional to the voltage.
a. true
b. false
5. Sine, square, dc, and triangle waves are all forms of ac.
a. true
b. false
6. The peak value of a sine wave is smaller in value than the rms value.
a. true
b. false
7. The following is a correct formula. $V_{p-p} = 1.414 \times V_{rms}$
a. true
b. false
8. The term rms means root mean square.
a. true
b. false
9. If an ac voltage is applied to a resistor the current will increase.
a. true
b. false
10. Commercial line voltages are usually square waves at a frequency of 60 Hz.
a. true
b. false
11. A formula for V_{p-p} is
a. $0.707 V_{rms}$
b. $0.707 V_p$
c. $2 V_p$
d. $2.8 V_p$

Chapter 8: Introduction to Alternating Current and Voltage

12. The rms value of a sine wave means
- the same as I_{p-p}
 - the root mean square value.
 - the heating effect of an ac generator of the same voltage.
 - the same as $I_p^2 R$
13. A sine wave has a peak value of 230 V. What is the instantaneous value at an angle of 42° ?
- 76.09 V
 - 115 V
 - 149 V
 - 153.9 V

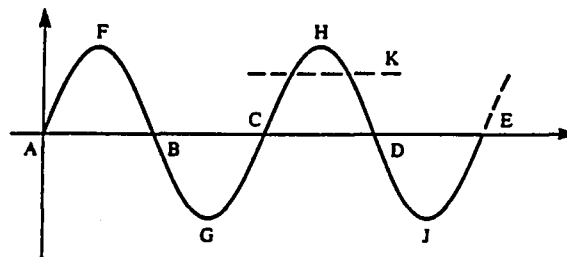


Figure 8-1

14. See figure 8-1. The value at point K is
- the period.
 - the rms voltage.
 - the p-p voltage.
 - V_p .
15. See figure 8-1. The time from points G to J is called
- the frequency.
 - V_p .
 - the period.
 - the rms voltage.
16. See figure 8-1. V_{p-p} would be measured from points
- A to F.
 - K to J.
 - B to D.
 - G to H.

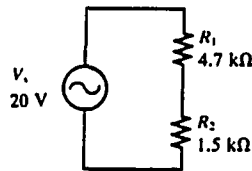
Chapter 8: Introduction to Alternating Current and Voltage

Figure 8-2

17. See figure 8-2. Find V_{R2} .
 - a. 6.84 V_{p-p}
 - b. 13.15 V_p
 - c. 6.84 V_p
 - d. 4.83 V_p
18. See figure 8-2. Find V_s .
 - a. 14.14 V_p
 - b. 56.6 V_{p-p}
 - c. 20 V_{p-p}
 - d. 28.28 V_{p-p}
19. The length of time for an ac wave form to start to repeat is called
 - a. the frequency.
 - b. alternating current.
 - c. revolutions per minute.
 - d. the period.
20. See figure 8-2. Solve for V_{R1p} .
 - a. 21.44 V_p
 - b. 6.84 V_p
 - c. 13.15 V_p
 - d. 13.68 V_p
21. A sine wave has a value of 22 V_{p-p}. What is the instantaneous value at an angle of 284°?
 - a. 10.67 V
 - b. 0.33 V
 - c. -10.67 V
 - d. -2.66 V
22. See figure 8-2. If R_1 opens, V_{R2} will
 - a. increase.
 - b. decrease.
 - c. remain the same.
 - d. not change since this is an ac source.

Chapter 8: Introduction to Alternating Current and Voltage

23. See figure 8-2 Find the instantaneous voltage across R_1 at an angle of 22° .
 - a. 8.03 V
 - b. 11.96 V
 - c. 2.56 V
 - d. 20.25 V
24. A square wave has a pulse width of 0.050 ms and a frequency of 4 kHz. Find the duty cycle of the square wave.
 - a. 80 %
 - b. 20 %
 - c. 1.25 %
 - d. 98.75 %
25. A square wave has a peak value of 10 V. It changes from 1 V to 9 V in 0.050 ms. This is called
 - a. fall time.
 - b. average value.
 - c. pulse width.
 - d. rise time.
26. A sine wave has a peak value of 169 V. What is the instantaneous value at an angle of 37° ?
 - a. 135 V
 - b. 119 V
 - c. 239 V
 - d. 102 V
27. See figure 8-1. The time from point B to C is called
 - a. an alternation.
 - b. the period.
 - c. a cycle.
 - d. peak voltage.
28. See figure 8-1. The voltage value at point H represents
 - a. rms voltage.
 - b. peak voltage.
 - c. p-p voltage.
 - d. one cycle of voltage.
29. See figure 8-2. Find V_{R1} .
 - a. 15.16 V
 - b. 21.43 V_{p-p}
 - c. 42.88 V_{peak}
 - d. 15.16 V_{peak}
30. See figure 8-2. Calculate I_{p-p} .
 - a. 4.55 mA
 - b. 3.22 mA
 - c. 9.12 mA
 - d. 6.44 mA

Chapter 8: Introduction to Alternating Current and Voltage

31. When a sine wave has a frequency of 60 Hz, in 10 s it goes through
a. 6 cycles
b. 10 cycles
c. 1/16 cycles
d. 600 cycles
32. If the peak value of a sine wave is 10 V, the peak-to-peak value is
a. 20 V
b. 5 V
c. 100 V
d. none of these
33. The instantaneous value of a 15 A peak sine wave at a point 32 degrees from its positive-going zero crossing is
a. 7.95 A
b. 7.5 A
c. 2.13 A
d. 7.95 A → 7.0095 A
34. If the rms current through a 10 k Ω resistor is 5 mA, the rms voltage drop across the resistor is
a. 70.7 V
b. 7.07 V
c. 5 V
d. 50 V
35. Two series resistors are connected to an ac source. If there is 6.5 V rms across one resistor and 3.2 V across the other, the peak source voltage is
a. 9.7 V
b. 9.19 V
c. 13.72
d. 4.53 V

Chapter 9: Capacitors

1. The measure of a capacitor's ability to store voltage is called capacitance.
 - a. true
 - b. false
2. A capacitor blocks dc and passes ac.
 - a. true
 - b. false
3. If two capacitors are in parallel across a dc source, the smaller capacitor has the larger voltage across it.
 - a. true
 - b. false
4. If the distance between the plates of a capacitor is increased, the capacitance decreases.
 - a. true
 - b. false
5. The time constant is the time required for a capacitor to fully charge.
 - a. true
 - b. false
6. The measure of a capacitor's ability to store resistance is called capacitance.
 - a. true
 - b. false
7. If two capacitors are in series across a dc source, the smallest capacitor has the largest voltage across it.
 - a. true
 - b. false
8. A capacitor will fully charge in about five time constants.
 - a. true
 - b. false
9. To find the total capacitance of two capacitors in parallel, you must combine them using a similar procedure as resistors in parallel.
 - a. true
 - b. false
10. If the area of the plates of a capacitor is decreased, then the capacitance will decrease.
 - a. true
 - b. false

Chapter 9: Capacitors

11. A capacitor has a charge of $0.500 \mu\text{C}$ and a voltage of 50 V across it. What is the capacitance?
 - a. $0.01 \mu\text{F}$
 - b. $1 \mu\text{F}$
 - c. $0.001 \mu\text{F}$
 - d. ~~$0.01 \mu\text{F}$~~ $1000 \mu\text{F}$
12. A $0.022 \mu\text{F}$ capacitor has a voltage of 22 V across it. What charge is stored on the capacitor?
 - a. $0.0484 \mu\text{C}$
 - b. $4.84 \mu\text{C}$
 - c. $0.484 \mu\text{C}$
 - d. $48.4 \mu\text{C}$
13. The dc working voltage of a capacitor is 100 V . This means that the dielectric must be able to withstand
 - a. 100 V dc .
 - b. $75 \text{ V}_{\text{rms}}$
 - c. $220 \text{ V}_{\text{rms}}$
 - d. $85 \text{ V}_{\text{rms}}$
14. Two capacitors are connected in parallel across 20 V . If $C_1 = 0.050 \mu\text{F}$ and $C_2 = 0.100 \mu\text{F}$, what are C_T and the voltage across each capacitor?
 - a. $0.15 \mu\text{F}$ and 10 V
 - b. $0.05 \mu\text{F}$ and 15 V
 - c. $0.10 \mu\text{F}$ and 20 V
 - d. $0.15 \mu\text{F}$ and 20 V
15. Three capacitors are in series. $C_1 = 0.022 \mu\text{F}$, $C_2 = 0.022 \mu\text{F}$, and $C_3 = 0.050 \mu\text{F}$. The source voltage is 25 V . What is the voltage across C_3 ?
 - a. 10.24 V
 - b. 11.76 V
 - c. 4.5 V
 - d. 17.5 V
16. A $4.7 \mu\text{F}$ is in series with a $22 \text{ k}\Omega$ resistor. What is the time constant?
 - a. 0.103 ms
 - b. 1.03 ms
 - c. 10.3 ms
 - d. 103 ms
17. A $0.047 \mu\text{F}$ capacitor is in series with a $100 \text{ k}\Omega$ resistor across a 20 V source. How long will it take for the capacitor to completely charge?
 - a. 2.35 s
 - b. 0.235 ms
 - c. 23.5 ms
 - d. 235 ms

Chapter 9: Capacitors

18. A $1.0\ \mu\text{F}$ capacitor is in series with a $47\ \text{k}\Omega$ resistor. The voltage across the capacitor is $25\ \text{V}$. How long will it take to completely discharge the capacitor through the resistor?
 - a. $47\ \text{s}$
 - b. $235\ \text{s}$
 - c. $47\ \text{ms}$
 - d. $235\ \text{ms}$
19. A $1\ \mu\text{F}$ capacitor is in series with a $10\ \text{k}\Omega$ resistor. A switch is closed applying $20\ \text{V}$ to the circuit. What will the voltage across the capacitor be after one time constant?
 - a. $17\ \text{V}$
 - b. $12.06\ \text{V}$
 - c. $10.99\ \text{V}$
 - d. $12.64\ \text{V}$
20. A $4.7\ \mu\text{F}$ capacitor is in series with a $10\ \text{k}\Omega$ resistor. A switch is closed, applying $25\ \text{V}$ to the circuit. What will the voltage across the resistor be after one time constant?
 - a. $9.2\ \text{V}$
 - b. $23.75\ \text{V}$
 - c. $21.63\ \text{V}$
 - d. $15.8\ \text{V}$
21. A $4.7\ \mu\text{F}$ is in a circuit with a frequency of $10\ \text{kHz}$. What value is X_c ?
 - a. $338.8\ \Omega$
 - b. $294\ \mu\Omega$
 - c. $3.388\ \Omega$
 - d. infinite
22. A $2000\ \text{pF}$ capacitor has an X_c of $745\ \Omega$. What is the operating frequency?
 - a. $106.8\ \text{Hz}$
 - b. $10.14\ \text{kHz}$
 - c. $1.014\ \text{kHz}$
 - d. $1014\ \text{Hz}$
23. An ohmmeter is used to test a capacitor. The reading in both directions is very high. The capacitor is probably
 - a. shorted.
 - b. leaking.
 - c. open.
 - d. completely charged.
24. A $22\ \mu\text{F}$ capacitor is connected to a $15\ \text{V}$, $400\ \text{Hz}$ source. The current will be
 - a. $55\ \text{mA}$
 - b. $18.1\ \text{mA}$
 - c. $829\ \text{mA}$
 - d. $1.81\ \text{A}$

Chapter 9: Capacitors

25. You want to check a large electrolytic capacitor with an ohmmeter. You place the leads across the capacitor and the meter reading starts at a low value and keeps increasing. The capacitor is
- open.
 - leaky.
 - shorted.
 - OK; this is normal.
26. Three capacitors are in series. $C_1 = 0.100 \mu\text{F}$, $C_2 = 0.100 \mu\text{F}$, and $C_3 = 0.050 \mu\text{F}$. The source voltage is 75 V. What is the voltage across C_3 ?
- 18.75 V
 - 50 V
 - 37.5 V
 - 100 V
27. A $0.047 \mu\text{F}$ capacitor is in series with a $1 \text{ M}\Omega$ resistor. How long will it take to completely charge the capacitor? The supply voltage is 50 V.
- 0.047 s
 - 0.029 s
 - 0.235 s
 - 0.47 s
28. A $0.1 \mu\text{F}$ capacitor is in series with a $2.2 \text{ k}\Omega$ resistor. A voltage of 30 V is applied when the switch is closed. What will the voltage across the capacitor be after one time constant?
- 29.4 V
 - 28.50 V
 - 25.95 V
 - 18.96 V
29. If the frequency applied to a capacitor is increased, the capacitive reactance will
- increase.
 - decrease.
 - remain the same.
 - vary up and down.
30. A capacitor which will transfer an ac signal from one stage to another is called a _____ capacitor.
- bypass
 - filter
 - coupling
 - transfer

Chapter 9: Capacitors

31. A $1\ \mu\text{F}$, a $2.2\ \mu\text{F}$, and a $0.05\ \mu\text{F}$ capacitor are connected in series. The total capacitance is less than
- a. $1\ \mu\text{F}$
 - b. $2.2\ \mu\text{F}$
 - c. $0.05\ \mu\text{F}$
 - d. $0.001\ \mu\text{F}$
32. Four $0.022\ \mu\text{F}$ capacitors are in parallel. The total capacitance is
- a. $0.02\ \mu\text{F}$
 - b. $0.08\ \mu\text{F}$
 - c. $0.05\ \mu\text{F}$
 - d. $0.04\ \mu\text{F}$
33. An uncharged capacitor and a resistor are connected in series with a switch and a $12\ \text{V}$ battery. At the instant the switch is closed, the voltage across the capacitor is
- a. $12\ \text{V}$
 - b. $6\ \text{V}$
 - c. $24\ \text{V}$
 - d. $0\ \text{V}$
34. An uncharged capacitor and a resistor are connected in series with a switch and a $12\ \text{V}$ battery. The voltage across the capacitor when it is fully charged is
- a. $12\ \text{V}$
 - b. $6\ \text{V}$
 - c. $24\ \text{V}$
 - d. $-6\ \text{V}$
35. An uncharged capacitor and a resistor are connected in series with a switch and a $12\ \text{V}$ battery. The capacitor will reach full charge in a time equal to approximately
- a. RC
 - b. $5\ RC$
 - c. $12\ RC$
 - d. cannot be predicted

Chapter 10: Inductors

1. The total inductance of inductors in parallel is the sum of all the inductances.
 - a. true
 - b. false
2. The energy stored in an inductor's electromagnetic field is produced by the current.
 - a. true
 - b. false
3. An inductor passes dc and opposes ac.
 - a. true
 - b. false
4. Inductive reactance decreases when the frequency is increased.
 - a. true
 - b. false
5. In an inductive circuit the voltage leads the current.
 - a. true
 - b. false
6. The energy stored in an inductor's electromagnetic field is produced by the resistance of the winding.
 - a. true
 - b. false
7. In an inductive circuit the voltage and current are in phase.
 - a. true
 - b. false
8. Inductances in series or parallel combine in a similar manner to resistors in series or parallel.
 - a. true
 - b. false
9. When a dc voltage is first applied to an inductor, the circuit current is zero.
 - a. true
 - b. false
10. If an inductor is placed in a circuit with ac applied, the voltage across the inductor leads the current through it.
 - a. true
 - b. false
11. A 50 mH inductor is in series with a 15 mH inductor. What is the total inductance?
 - a. 11.5 mH
 - b. 15 mH
 - c. 50 mH
 - d. 65 mH

Chapter 10: Inductors

12. A 12 mH inductor is in series with a 10 k Ω resistor. The source voltage is 15 V. What is the maximum current?
 - a. 1.2 mA
 - b. 1.5 mA
 - c. 2.2 mA
 - d. 6.32 mA
13. An inductor has an ac current flowing through it. The magnetic field is
 - a. steady.
 - b. constantly changing.
 - c. moving from south to north.
 - d. collapsed.
14. You have two inductors. One inductor has an iron core, and the other inductor has an air core. Which inductor probably has the larger inductance?
 - a. air core
 - b. neither; both have the same
 - c. iron core
 - d. there is no way to tell
15. A 50 mH inductor has a voltage of 25 V with a frequency of 22 kHz applied to it. What is X_L ?
 - a. 6908 Ω
 - b. 500 Ω
 - c. 113 Ω
 - d. 69 Ω
16. In an inductive circuit, the _____ lags the _____.
 - a. voltage, resistance
 - b. current, voltage
 - c. current, resistance
 - d. voltage, reactance
17. A 27 mH inductor has an X_L of 5.5 k Ω . What is the applied frequency?
 - a. 932 Hz
 - b. 324 Hz
 - c. 3.24 kHz
 - d. 32.4 kHz
18. A 10 mH inductor is in series with a 47 k Ω resistor. What is the time constant?
 - a. 0.213 μ s
 - b. 470 s
 - c. 213 s
 - d. 470 ms

Chapter 10: Inductors

19. An inductor has a magnetic field around it. How many time constants will it take to collapse the field completely?
 - a. 1
 - b. 3
 - c. 4
 - d. 5
20. An inductor with an inductance of 0.2 mH and a resistance of 20 Ω is applied to a 1 MHz source. What is the inductive reactance?
 - a. 1.256 M Ω
 - b. 125.6 k Ω
 - c. 1.256 k Ω
 - d. 125.6 Ω
21. An inductor is in an ac circuit with a voltage of 12 V. The current is 50 mA. What is X_L ?
 - a. 6 Ω
 - b. 60 Ω
 - c. 600 Ω
 - d. 240 Ω
22. You believe you have a faulty inductor. The resistance measures infinite. The dc voltage across the coil equals the source voltage. The probable fault, if any, is that
 - a. the coil is shorted.
 - b. the coil is open.
 - c. the coil is normal.
 - d. the coil will work on ac.
23. A 20 mH inductor is in parallel with a 50 mH inductor. The total inductance is
 - a. 20 mH
 - b. 50 mH
 - c. 70 mH
 - d. 14.29 mH
24. You have an application that will use an inductance of 65 mH. You have one inductor with a value of 100 mH. What value must the other inductor have to equal the desired total value? How will the circuit be connected?
 - a. 185.7 mH, in series
 - b. 185.7 mH, in parallel
 - c. 35 mH, in parallel
 - d. 35 mH, in series
25. A coil of wire is carrying a dc current of 100 mA. The X_L of the coil is 600 Ω at 60 Hz. The voltage across the coil is 30 V. What is the resistance of the coil?
 - a. 600 Ω
 - b. 60 Ω
 - c. 300 Ω
 - d. 30 Ω

Chapter 10: Inductors

26. Two 2.5 mH inductors are in series with a 4.7 k Ω resistor. The source voltage is 100 V. What is the maximum current in this circuit?
- 21.3 mA
 - 63.2 mA
 - 1.1 mA
 - 7.9 mA
27. A frequency of 10 kHz is applied to a coil with an inductance of 150 mH. What is the inductance reactance?
- 1500 Ω
 - 6280 Ω
 - 8450 Ω
 - 9420 Ω
28. A 50 mH inductor is in series with a 5 k Ω resistor. What is the time constant?
- 10 μ s
 - 100 s
 - 250 s
 - 10 ms
29. A 40 mH inductor is in parallel with a 24 mH inductor. The total inductance is
- 64 mH.
 - 32 mH.
 - 15 mH.
 - 150 mH.
30. You think that an inductor is faulty. You measure the resistance at zero ohms. The dc voltage across the coil measures zero. The probable fault, if any, is
- the coil is shorted.
 - the coil is open.
 - the coil is normal.
 - the coil will work on ac.
31. An inductance of 0.05 μ H is larger than
- 0.0000005 H
 - 0.000005 H
 - 0.000000008 H
 - 0.00005 H
32. An inductance of 0.33 mH is smaller than
- 33 μ H
 - 330 μ H
 - 0.05 mH
 - 0.0005 H

Chapter 10: Inductors

33. Four 10 mH inductors are in series. The total inductance is ;
a. 40 mH
b. 2.5 mH
c. 40,000 μ H
d. both a and c
34. A 1 mH, a 3.3 mH, and a 0.1 mH inductor are connected in parallel. The total inductance is
a. 4.4 mH
b. greater than 3.3 mH
c. less than 0.1 mH
d. both a and b
35. An inductor, a resistor, and a switch are connected in series to a 12 V battery. At the instant the switch is closed, the inductor voltage is
a. 0 V
b. 12 V
c. 6 V
d. 4 V

Chapter 11: Transformers

1. Only the number of turns in the primary and secondary of a transformer determines the actual secondary voltage.
a. true
b. false
2. A transformer can be used as an impedance matching device.
a. true
b. false
3. A step-down transformer could have a primary-secondary turns ratio of 4:1.
a. true
b. false
4. Transformer cores are made from laminated iron to reduce losses.
a. true
b. false
5. The efficiency of transformers is very low.
a. true
b. false
6. A transformer with a turns ratio of 1:1 is often used to isolate a load from a source.
a. true
b. false
7. A transformer with a turns ratio of 1:7 is a step down transformer.
a. true
b. false
8. If a dc voltage is applied to the primary of a transformer, an ac voltage is induced in the secondary.
a. true
b. false
9. An ideal transformer has no power loss.
a. true
b. false
10. A typical transformer fault would be an open winding.
a. true
b. false
11. A step-up transformer will decrease _____ and increase _____.
a. current, resistance
b. current, voltage
c. voltage, current
d. resistance, current

Chapter 11: Transformers

12. The hysteresis loss in a transformer is
 - a. due to current flowing in the core.
 - b. caused by rapid reversal of the magnetic field.
 - c. caused by the resistance of the wire.
 - d. another name for flux leakage loss.
13. Eddy current loss in a transformer is
 - a. due to current flowing in the core.
 - b. caused by rapid reversal of the magnetic field.
 - c. caused by the resistance of the wire.
 - d. another name for flux leakage loss.
14. When a source is connected to a load, maximum power is delivered to the load when the load resistance is equal to the source resistance. This is a definition of
 - a. Lenz's Law.
 - b. Ohm's Law.
 - c. Maximum power transfer theorem.
 - d. Kirchhoff's Law.

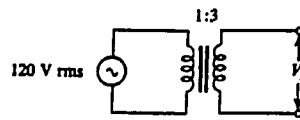


Figure 11- 1

15. See figure 11-1. There are three times as many turns in the secondary as in the primary. What is the secondary voltage V_s ?
 - a. 40
 - b. 80 V
 - c. 240 V
 - d. 360 V
16. See figure 11-1. If the ratio of primary to secondary turns were changed to 7:1, what is the output voltage V_s ?
 - a. 17.14 V
 - b. 840 V
 - c. 8.59 V
 - d. 420 V
17. See figure 11-1. If the primary to secondary turns ratio is changed to 3:1, and a load resistor of $100\ \Omega$ is in the secondary, what is the secondary current I_s ?
 - a. 33 mA
 - b. 40 mA
 - c. 330 mA
 - d. 400 mA

Chapter 11: Transformers

18. See figure 11-1. The primary-secondary turns ratio is kept at 1:3 and I_s is 240 mA. What is the primary current I_p ?
- 60 mA
 - 120 mA
 - 720 mA
 - 1.2 A
19. See figure 11-1. The primary-secondary turns ratio is 3:1 and I_s is 240 mA. What is the reflected resistance seen by the primary?
- 167 Ω
 - 500 Ω
 - 1500 Ω
 - 9000 Ω
20. A circuit is giving you problems. The power transformer is delivering a low output voltage. The input voltage to the transformer is correct. A probable trouble is
- an open secondary.
 - a shorted primary.
 - an open primary.
 - a partially shorted secondary.
21. You are going to buy a matching transformer to match a 600 Ω audio signal distribution line to an 8 Ω speaker. The primary should have _____ more turns than the secondary.
- 8.66
 - 75
 - 0.013
 - 0.115
22. You need to couple two circuits together with no change in either voltage or current. The correct transformer to use would be
- a step-up type.
 - an isolation type.
 - a step-down type.
 - a power type.
23. A common use for a transformer is to
- convert a lower current into a higher current.
 - convert a higher voltage into a lower voltage.
 - match the impedance of a source to the impedance of a load.
 - all of these
 - none of these

Chapter 11: Transformers

24. A power transformer for a TV set has a primary winding designed to operate with an ac voltage of 125 V. This transformer has four secondary windings, all of the same gage wire. You measure the resistance of each secondary winding and find that one has the lowest resistance. Which winding will have the lowest resistance?
- the 550 V secondary
 - the 6.3 V secondary
 - the 12 V secondary
 - the 5 V secondary
25. The center tapped secondary winding of a transformer gives unequal voltages on each half of the secondary. This is causing your power amplifier to work improperly. What is a probable solution?
- Add some turns to the half with the lower voltage winding.
 - Remove some turns from the half with the higher voltage winding.
 - Replace the transformer.
 - Do not concern yourself; the customer will probably not notice the problem.
26. A step-up transformer will increase_____ and decrease_____.
- voltage, impedance
 - current, impedance
 - voltage, power
 - power, current
27. See figure 11-1. If the ratio of primary to secondary turns is changed to 4.5:1, what is the output voltage V_s ?
- 540 V
 - 26.67 V
 - 5.92 V
 - 4.72 V
28. See figure 11-1. If the primary to secondary turns ratio is changed to 4:1, and a load resistor of 50 ohms is in the secondary, what is the secondary current?
- 1.66 A
 - 600 mA
 - 9.6 A
 - 4.8 A
29. See figure 11-1. The primary-secondary turns ratio is changed to 4:1 and $I_p = 40$ mA. What is the primary current?
- 160 mA
 - 40 mA
 - 10 mA
 - 4 mA

Chapter 11: Transformers

30. See figure 11-1. The primary-secondary turns ratio is changed to 4:1 and $I_s = 40$ mA. What is the reflected resistance seen by the primary?
- a. 4 k Ω
 - b. 8 k Ω
 - c. 12 k Ω
 - d. 16 k Ω
31. When the turns ratio of a transformer is 1:10 and the primary ac voltage is 6 V, the secondary voltage is
- a. 60 V
 - b. 0.6 V
 - c. 6 V
 - d. 36 V
32. If 10 W of power are applied to the primary of an ideal transformer with a turns ratio of 1:5, the power delivered to the secondary load is
- a. 50 W
 - b. 0.5 W
 - c. 0 W
 - d. 10 W
33. When a 1 k Ω load resistor is connected across the secondary winding of a transformer with a turns ratio of 1:2, the source "sees" a reflected load of
- a. 250 Ω
 - b. 2 k Ω
 - c. 4 k Ω
 - d. 1 k Ω
34. When a 1 k Ω load resistor is connected across the secondary winding of a transformer with a turns ratio of 2:1, the source "sees" a reflected load of
- a. 1 k Ω
 - b. 2 k Ω
 - c. 4 k Ω
 - d. 500 Ω
35. The turns ratio required to match a 50 Ω source to a 200 Ω load is
- a. 4:1
 - b. 2:1
 - c. 1:4
 - d. 1:2

Chapter 12: Frequency Response of RC Circuits

1. The total current in an RC circuit always leads the source voltage.
a. true
b. false
2. The phasor combination of V_R and V_C in an RC series circuit is called the source voltage, V_S .
a. true
b. false
3. An RC circuit can be used as a filter to eliminate certain frequencies.
a. true
b. false
4. As the frequency applied to an RC circuit is decreased, the phase angle decreases.
a. true
b. false
5. As the frequency applied to an RC circuit is varied, X_C and resistance also vary.
a. true
b. false
6. The total current in an RC circuit always lags the source voltage.
a. true
b. false
7. The phasor combination of X_C and R is called Z .
a. true
b. false
8. As the frequency applied to an RC circuit is increased, the impedance decreases.
a. true
b. false
9. The phase angle of an RC circuit varies inversely with frequency.
a. true
b. false
10. When the frequency applied to an RC circuit is varied, the value of X_C varies.
a. true
b. false

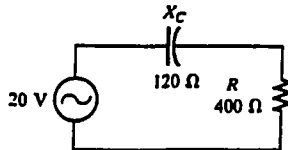
Chapter 12: Frequency Response of RC Circuits

Figure 12-1

11. See figure 12-1. If the frequency is 60 Hz, what is the value of capacitance?
 - a. 22 μF
 - b. 44 μF
 - c. 66 μF
 - d. 88 μF
12. See figure 12-1. If the source voltage is changed to 50 V, find the impedance.
 - a. 120 Ω
 - b. 280 Ω
 - c. 418 Ω
 - d. 520 Ω
13. See figure 12-1. If the source voltage is changed to 50 V, calculate the true power.
 - a. 916 mW
 - b. 5.72 mW
 - c. 5.72 W
 - d. 275 mW
14. See figure 12-1. If the operating frequency is increased, what effect will that increase have on the current?
 - a. It will increase.
 - b. It will remain the same.
 - c. It will decrease.
 - d. It will decrease to zero.
15. See figure 12-1. If the operating frequency is increased, what effect will that increase have upon the phase angle?
 - a. It will increase.
 - b. It will remain the same.
 - c. It will decrease.
 - d. It will change to another quadrant.

Chapter 12: Frequency Response of RC Circuits

16. See figure 12-1. If the operating frequency is increased, what effect will it have on the value of the resistor?
- It will increase.
 - It will remain the same.
 - It will decrease.
 - It will open.

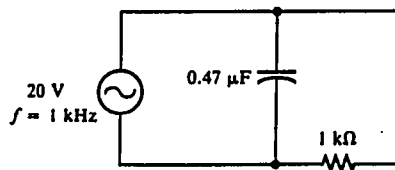


Figure 12-2

17. See figure 12-2. If the resistor is changed to $47 \text{ k}\Omega$, what effect will that change have upon the total current?
- It will increase.
 - It will remain the same.
 - It will decrease.
 - It will decrease to zero.
18. See figure 12-2. Calculate the voltage drop across the resistor.
- 10 V
 - 20 V
 - 59 mV
 - 19.94 V
19. See figure 12-2. You need to increase the power factor. What changes could you make to accomplish this?
- Increase the value of V_s .
 - Increase the value of the resistor.
 - Increase the value of the capacitor.
 - Decrease the value of the capacitor.
20. See figure 12-2. Which statement describes the relationship of I_C to I_R ?
- They are in phase.
 - I_C leads I_R .
 - I_C lags I_R .
 - They are 180° out of phase.

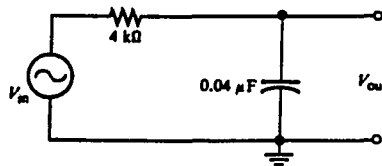
Chapter 12: Frequency Response of RC Circuits

Figure 12-3

21. See figure 12-3. This circuit is known as
 - a. a high-pass filter.
 - b. a band-pass filter.
 - c. a low-pass filter.
 - d. parallel RC circuit.
22. See figure 12-3. If the resistor is changed to 47 kΩ, what is the new cutoff frequency?
 - a. 85 Hz
 - b. 118 Hz
 - c. 995 Hz
 - d. 1012 Hz
23. See figure 12-3. If the input voltage were constant at 22 V for all incoming frequencies, what would the output voltage be at the cutoff frequency?
 - a. 6.446 V
 - b. 31.12 V
 - c. 15.554 V
 - d. 22 V
24. See figure 12-3. If the output were taken across the resistor, the circuit would be known as a _____ filter.
 - a. low-pass
 - b. high-pass
 - c. band-pass
 - d. band-notch
25. See figure 12-3. This filter has an output voltage that is too high at the cutoff frequency. Determine a possible trouble that could cause this output.
 - a. The resistor has opened.
 - b. The capacitor has shorted.
 - c. The resistor has shorted.
 - d. The capacitor has become leaky.
26. See figure 12-1. Calculate the voltage drop across the capacitor.
 - a. 19.14 V
 - b. 16.7 V
 - c. 20 V
 - d. 5.75 V

Chapter 12: Frequency Response of RC Circuits

27. See figure 12-1. Calculate the apparent power.
a. 0.874 VA
b. 0.916 VA
c. 0.957 VA
d. 0.989 VA
28. See figure 12-2. Find the total impedance.
a. 1000 Ω
b. 880 Ω
c. 321 Ω
d. 62 Ω
29. See figure 12-1. If the frequency is increased, the phase angle will _____ and the impedance will _____.
a. decrease, increase
b. decrease, decrease
c. increase, decrease
d. increase, increase
30. See figure 12-3. The cutoff frequency is
a. 6250 Hz.
b. 99 Hz.
c. 480 Hz.
d. 995 Hz.
31. In a series RC circuit, 10 V_{rms} is measured across the resistor and 10 V_{rms} is also measured across the capacitor. The rms source voltage is
a. 20 V
b. 14.14 V
c. 28.28 V
d. 10 V
32. In a parallel RC circuit, there is 1 A_{rms} through the resistive branch and 1 A_{rms} through the capacitive branch. The total rms current is
a. 1 A
b. 2 A
c. 2.28 A
d. 1.414 A
33. A power factor of 1 indicates that the circuit phase angle is
a. 90°
b. 45°
c. 180°
d. 0°
34. For a certain load, the true power is 100 W and the reactive power is 100 VAR. The apparent power is
a. 200 VA
b. 100 VA
c. 141.4 VA
d. 141.4 W

Chapter 12: Frequency Response of RC Circuits

35. If the bandwidth of a certain low-pass is 1 kHz, the cutoff frequency is
- a. 0 Hz
 - b. 500 Hz
 - c. 2 kHz
 - d. 1000 Hz

Chapter 13 : Frequency Response of RL Circuits

1. The source voltage always leads the total current in an RL circuit.
a. true
b. false
2. A low-pass filter passes high frequencies and blocks other frequencies.
a. true
b. false
3. The impedance of an RL series circuit varies inversely with the frequency.
a. true
b. false
4. In a filter circuit using RL components, a decrease in the value of R will increase the cutoff frequency.
a. true
b. false
5. The impedance of a series RL circuit is found by adding the values of X_L and R.
a. true
b. false
6. The source voltage always lags the total current in an RL circuit.
a. true
b. false
7. A high-pass filter passes high frequencies and blocks low frequencies.
a. true
b. false
8. In an RL circuit, if the frequency is increased, the impedance will decrease.
a. true
b. false
9. In a filter circuit using RL components, an increase in the value of inductance will increase the cutoff frequency.
a. true
b. false
10. The impedance of a series RL circuit is found by adding the values of X_L and R using a phasor diagram.
a. true
b. false

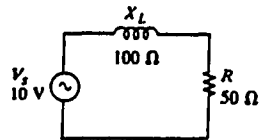
Chapter 13 : Frequency Response of RL Circuits

Figure 13- 1

11. See figure 13-1. If the frequency is 60 Hz, what is the value of the inductance?
 - a. 265 mH
 - b. 3.768 H
 - c. 26.5 mH
 - d. 3.768 mH
12. See figure 13-1. If the source voltage is changed to 50 V, find the impedance.
 - a. 104 Ω
 - b. 112 Ω
 - c. 1120 Ω
 - d. 1040 Ω
13. See figure 13-1. If the source voltage is changed to 50 V, calculate the true power.
 - a. 1 W
 - b. 400 mW
 - c. 4 W
 - d. 10 W
14. See figure 13-1. If the operating frequency is increased, the current will
 - a. increase.
 - b. decrease.
 - c. remain the same.
 - d. decrease to zero.
15. See figure 13-1. If the operating frequency is increased, the phase angle will
 - a. increase.
 - b. decrease
 - c. remain the same.
 - d. change to another quadrant.
16. See figure 13-1. If the operating frequency is increased, the value of inductance will
 - a. increase.
 - b. decrease
 - c. remain the same.
 - d. decrease to zero.

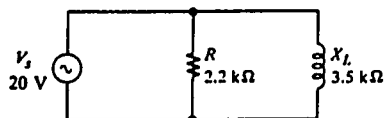
Chapter 13 : Frequency Response of RL Circuits

Figure 13-2

17. See figure 13-2. If the value of the resistor is changed to 47 kΩ, the total current will
 - a. increase.
 - b. decrease.
 - c. remain the same.
 - d. decrease to zero.
18. See figure 13-2. You need to increase the power factor. What change could you make to accomplish this?
 - a. Increase the source voltage.
 - b. Decrease the source voltage.
 - c. Decrease the value of the resistor.
 - d. Increase the value of the resistor.
19. See figure 13-2. Which statement describes the relationship of I_L to I_R ?
 - a. They are in phase.
 - b. I_L leads I_R .
 - c. I_L lags I_R .
 - d. They are 180° out of phase.

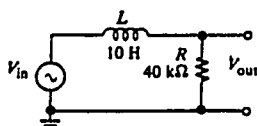


Figure 13-3

20. See figure 13-3. This circuit is known as a _____ filter.
 - a. low-pass
 - b. high-pass
 - c. band-pass
 - d. notch
21. See figure 13-3. If the resistor is changed to 50 kΩ, find the new cutoff frequency.
 - a. 637 Hz
 - b. 796 Hz
 - c. 637 kHz
 - d. 7.96 kHz

Chapter 13 : Frequency Response of RL Circuits

22. See figure 13-3. If the input voltage is constant at 47 V for all frequencies, find V_{out} at the cutoff frequency.
- 6.77 V
 - 33.3 V
 - 29.7 V
 - 17.3 V
23. See figure 13-3. Some of the turns of the inductor have shorted. What effect will this have on the circuit operation?
- The cutoff frequency will increase.
 - The cutoff frequency will decrease.
 - The output voltage at the cutoff frequency will increase.
 - The output voltage at the cutoff frequency will decrease.
24. See figure 13-1. If the frequency decreases, the phase angle will _____, and the current will _____.
- increase, increase
 - decrease, decrease
 - increase, decrease
 - decrease, increase
25. See figure 13-3. If the output were taken across the inductor, the circuit would be known as a _____ filter.
- low-pass
 - high-pass
 - band-pass
 - notch
26. See figure 13-1. Find the voltage across the inductor.
- 0.4 V
 - 0.894 V
 - 4.47 V
 - 8.94 V
27. See figure 13-1. Find the apparent power.
- 0.4 VA
 - 0.8 VA
 - 8.94 VA
 - 0.894 VA
28. See figure 13-2. Find the total impedance.
- 1.074 k Ω
 - 9.09 k Ω
 - 5.71 k Ω
 - 1.86 k Ω
29. See figure 13-1. If the frequency is increased, the phase angle will _____ and the impedance will _____.
- decrease, increase
 - decrease, decrease
 - increase, decrease
 - increase, increase

Chapter 13 : Frequency Response of RL Circuits

30. See figure 13-3. Find the cutoff frequency.
 - a. 2.5 MHz
 - b. 637 Hz
 - c. 1.2 MHz
 - d. 408 Hz
31. In a series RL circuit, 10 V_{rms} is measured across the resistor, and 10 V_{rms} is measured across the inductor. The peak value of the source voltage is
 - a. 14.14 V
 - b. 28.28 V
 - c. 10 V
 - d. 20 V
32. In a parallel RL circuit, there are 2 A_{rms} in the resistive branch and 2 A_{rms} in the inductive branch. The total rms current is
 - a. 4 A
 - b. 5.656 A
 - c. 2 A
 - d. 2.828 A
33. If a load is purely inductive and the reactive power is 10 VAR, the apparent power is
 - a. 0 VA
 - b. 10 VA
 - c. 14.14 VA
 - d. 3.16 VA
34. For a certain load, the true power is 10 W and the reactive power is 10 VAR. The apparent power is
 - a. 5 VA
 - b. 20 VA
 - c. 14.14 VA
 - d. 100 VA
35. The cutoff frequency of a certain low-pass RL filter is 20 kHz. The filter's bandwidth is
 - a. 20 kHz
 - b. 40 kHz
 - c. 0 kHz
 - d. unknown

Chapter 14: Resonant Circuits

1. The total impedance of a series RLC circuit at resonance is equal to the resistance.
a. true
b. false
2. At resonance, a parallel RLC circuit is capacitive.
a. true
b. false
3. At resonance, it is usual for X_C to equal X_L .
a. true
b. false
4. The bandwidth of a resonant circuit varies inversely with Q . As Q increases, the bandwidth decreases.
a. true
b. false
5. A series resonant circuit has minimum impedance and maximum current.
a. true
b. false
6. A parallel resonant circuit has minimum impedance and maximum line current.
a. true
b. false
7. At resonance, a parallel RLC circuit is inductive.
a. true
b. false
8. At resonance, a series RLC circuit has an impedance equal to the resistance.
a. true
b. false
9. At resonance, a series RLC circuit has maximum current.
a. true
b. false
10. A resonant RLC circuit is said to be very selective if Q has a low value.
a. true
b. false

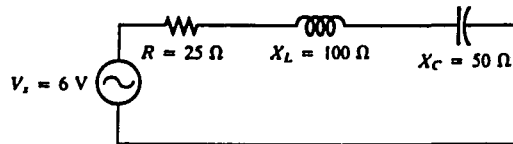
Chapter 14: Resonant Circuits

Figure 14-1

11. See figure 14-1. Find the voltage across the capacitor.
 - a. 5.37 V
 - b. 0.633 V
 - c. 10.7 V
 - d. -4.9 V
12. See figure 14-1. If you desired to operate this circuit at resonance, you will _____ the resistance and _____ the frequency.
 - a. increase, increase
 - b. decrease, decrease
 - c. not change, increase
 - d. not change, decrease
13. See figure 14-1. If the frequency of the source voltage is increased, the impedance will _____ and the current will _____.
 - a. decrease, decrease
 - b. decrease, increase
 - c. increase, increase
 - d. increase, decrease
14. See figure 14-1. If the resistance R , were increased, the impedance would
 - a. increase
 - b. decrease
 - c. remain the same
 - d. become zero

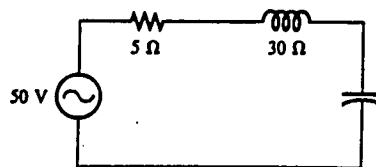


Figure 14-2

Chapter 14: Resonant Circuits

15. See figure 14-2. If the value of R were increased, the bandwidth would
 - a. increase.
 - b. remain the same.
 - c. decrease.
 - d. vary.
16. See figure 14-2. If the capacitor opens, the current would
 - a. increase because of the inductor.
 - b. not change.
 - c. decrease.
 - d. continue but the circuit would not be resonant.
17. A resonant circuit with a low Q means that it
 - a. has a narrow pass-band.
 - b. tunes sharply.
 - c. has a wide pass-band.
 - d. has a small voltage across the capacitor.
18. The resonant frequency of a tank circuit with $L = 50 \text{ mH}$ and $C = 256 \text{ pF}$ is
 - a. 44.5 Hz
 - b. 44.5 kHz
 - c. 445 kHz
 - d. 4.45 MHz
19. What is the bandwidth of a circuit resonant at 14.2 MHz, if $X_C = 3.5 \text{ k}\Omega$ and the coil resistance is 8 ohm?
 - a. 28.4 kHz
 - b. 2285 Hz
 - c. 14.2 MHz
 - d. 32.5 kHz
20. A circuit with $X_L = 1.2 \text{ k}\Omega$ is resonant at 22 kHz. If $R = 60 \Omega$, $f_1 = \underline{\hspace{2cm}}$ and $f_2 = \underline{\hspace{2cm}}$.
 - a. 21.45 kHz, 22.55 kHz
 - b. 21.82 kHz, 22.18 kHz
 - c. 20.9 kHz, 23.1 kHz
 - d. 21.7 kHz, 22.3 kHz
21. The impedance of a parallel resonant circuit is $0.22 \text{ M}\Omega$. $Q = 100$ and $V_s = 50 \text{ V}$. Find the tank current.
 - a. 0.227 mA
 - b. 0.5 mA
 - c. 5 mA
 - d. 22.7 mA

Chapter 14: Resonant Circuits

22. A series circuit resonant at 14 MHz has a source voltage of 12 V. The output voltage across the inductor is 300 V. What is the ratio of V_o/V_s expressed in dB?
- 25 dB
 - 13.98 dB
 - 27.96 dB
 - 42.91 dB
23. A resonant circuit is delivering 120 W. What is the power at f_1 and f_2 ?
- 84.84 W
 - 84.84 W at f_1 and 60 W at f_2
 - 60 W
 - 17 W at both frequencies
24. A tank circuit is operating at a frequency below resonance. The circuit is _____ in nature.
- resistive
 - capacitive
 - inductive
 - positive
25. You are working on a tuned tank circuit. This circuit tunes with a very narrow bandwidth. Q might be
- very low.
 - very high.
 - about 10.
 - below 10.
26. See figure 14-1. If the frequency of the source voltage is decreased a little, the impedance will _____ and the phase angle will _____.
- increase, increase
 - increase, decrease
 - decrease, decrease
 - decrease, increase
27. See figure 14-2. At resonance the current will be
- 10 A
 - 10 mA
 - 1.66 A
 - 1.66 mA
28. In a parallel resonant RLC circuit, the impedance is _____ and the total current is _____.
- maximum, maximum
 - maximum, minimum
 - minimum, minimum
 - minimum, maximum

Chapter 14: Resonant Circuits

29. The resonant frequency of a tank circuit with $L = 0.150 \text{ mH}$ and with $C = 300 \text{ pF}$ is
a. 1.65 MHz.
b. 751 kHz.
c. 347 kHz.
d. 6.05 MHz.
30. A circuit is resonant at 1 MHz. $Q = 50$. $f_1 = \underline{\hspace{1cm}}$ and $f_2 = \underline{\hspace{1cm}}$.
a. 0.98 MHz, 1.01 MHz
b. 0.99 MHz, 1.01 MHz
c. 0.99 MHz, 1.02 MHz
d. 0.98 MHz, 1.02 MHz
31. The impedance at the resonant frequency of a series RLC circuit with $L = 15 \text{ mH}$, $C = 0.015 \text{ }\mu\text{F}$, and $R = 80 \text{ }\Omega$ is
a. 15 k Ω
b. 80 Ω
c. 30 Ω
d. 0 Ω
32. In a certain series resonant circuit, $V_C = 150 \text{ V}$, $V_L = 150 \text{ V}$, and $V_R = 50 \text{ V}$. The value of the source voltage is
a. 150 V
b. 300 V
c. 50 V
d. 350 V
33. A certain series resonant band-pass filter has a bandwidth of 1 kHz. If the existing coil is replaced with one having a lower value of Q , the bandwidth will
a. increase
b. decrease
c. remain the same
d. be more selective
34. The total current into the L and C branches at resonance is ideally
a. maximum
b. low
c. high
d. zero
35. The total reactance of a series RLC circuit at resonance is
a. zero
b. equal to the resistance
c. infinity
d. capacitive

Chapter 15: Pulse Response of RC and RL Circuits

1. In an RC integrating circuit, the output is taken across the capacitor.
a. true
b. false
2. In an RC integrator, when the pulse width of the input is much less than 5τ , the output approaches the shape of the input.
a. true
b. false
3. In an RL integrating circuit, the output is taken across the inductor.
a. true
b. false
4. It takes a capacitor 5 time constants to charge completely.
a. true
b. false
5. An RC differentiating circuit has the output taken across the resistor.
a. true
b. false
6. An RC integrating circuit is a basic high-pass filter with a pulse applied to it.
a. true
b. false
7. The output of an RC integrator is the capacitor voltage.
a. true
b. false
8. An RL integrator is a basic RL low-pass filter with a pulse applied to it.
a. true
b. false
9. In an RC integrator, as the time constant gets longer, the maximum capacitor voltage gets smaller.
a. true
b. false
10. The output waveform of an RL integrator is exactly the same as the RC integrator with similar characteristics.
a. true
b. false

Chapter 15: Pulse Response of RC and RL Circuits

11. An RC integrating circuit has a $47\text{ k}\Omega$ resistor in series with a $0.01\text{ }\mu\text{F}$ capacitor. What is the time constant?
 - a. 0.047 ms
 - b. $0.047\text{ }\mu\text{s}$
 - c. 0.47 ms
 - d. 0.47 s
 12. An integrating circuit has a $10\text{ k}\Omega$ resistor in series with a $470\text{ }\mu\text{F}$ capacitor. What is the time constant?
 - a. $0.047\text{ }\mu\text{s}$
 - b. $0.47\text{ }\mu\text{s}$
 - c. 0.47 ms
 - d. 4.7 s
 13. A $1.2\text{ M}\Omega$ resistor is in series with a $22\text{ }\mu\text{F}$ capacitor. How long will it take to completely charge the capacitor? The source voltage is 12 V .
 - a. 132 s
 - b. 26.4 s
 - c. 0.264 s
 - d. 2.64 s
 14. A $0.047\text{ }\mu\text{F}$ capacitor is charged to 12 V . You discharge it through a $10\text{ k}\Omega$ resistor. How long will it take to completely discharge the capacitor?
 - a. 5 s
 - b. 0.47 ms
 - c. 2.35 ms
 - d. 0.18 ms
 15. A 15 V pulse is applied to an RC integrator. The pulse width equals one time constant. Find V_c at the end of the pulse.
 - a. 14.7 V
 - b. 14.25 V
 - c. 12.975 V
 - d. 9.48 V
 16. An RC integrator uses a $0.47\text{ }\mu\text{F}$ capacitor and a $5\text{ k}\Omega$ resistor. A single 15 V pulse is applied for 4.7 ms . Find V_c at the end of the pulse.
 - a. 9.48 V
 - b. 12.975 V
 - c. 14.25 V
 - d. 14.7 V
 17. An RC differentiator circuit uses a $0.01\text{ }\mu\text{F}$ capacitor and a $10\text{ k}\Omega$ resistor. The input signal is a square wave with a very short pulse width compared to the time constant. The output signal will be
 - a. zero volts.
 - b. a square wave very similar to the input voltage.
 - c. a dc value of about half the peak input voltage.
 - d. a dc voltage equal to the peak input voltage.
-

Chapter 15: Pulse Response of RC and RL Circuits

18. An RL differentiator has the output taken _____ the _____.
- across, resistor
 - across, resistor and inductor
 - across, inductor
 - in parallel with, resistor
19. You are trying to completely charge a 100 μF capacitor in 15 seconds. Find the value of the necessary resistor.
- 15 $\text{k}\Omega$
 - 30 $\text{k}\Omega$
 - 25 $\text{k}\Omega$
 - 35 $\text{k}\Omega$
20. An RL integrator circuit uses an inductor of 2 H and a resistor of 22 $\text{k}\Omega$. A pulse with a peak voltage of 12 V is applied for 0.0909 ms. What is the output voltage at the end of the pulse?
- 7.58 V
 - 10.38 V
 - 11.4 V
 - 11.76 V
21. An RL integrator circuit has a 200 mH inductor and a 1.2 $\text{k}\Omega$ resistor. A 5 V dc voltage has been applied to the circuit for 1.2 ms. What is the output voltage at the end of the pulse?
- 3.16 V
 - 4.532 V
 - 4.75 V
 - 5 V
22. An RC integrator circuit has a 10 second 50 V pulse applied to it. If $R = 10 \text{ k}\Omega$ and $C = 100 \mu\text{F}$, what is the output voltage at the end of the pulse?
- 31.6 V
 - 43.25 V
 - 47.5 V
 - 50 V
23. How does the RC differentiator output look when 5τ is much less than the pulse width?
- positive spikes
 - positive and negative spikes
 - negative spikes
 - square waves

Chapter 15: Pulse Response of RC and RL Circuits

24. A 22 V pulse with a width of 2 ms is applied to an RL integrator with $L = 1 \text{ H}$ and $R = 1 \text{ k}\Omega$. What is the output voltage at the end of the pulse?
- 13.9 V
 - 19.03 V
 - 20.9 V
 - 21.56 V
25. RC and RL integrators provide _____ output(s) when the inputs are _____.
a. the same, different
b. different, different
c. the same, the same
d. different, same
26. An integrating circuit has a $4.7 \text{ k}\Omega$ resistor in series with a $0.005 \text{ }\mu\text{F}$ capacitor. What is the time constant?
- 0.0235 ms
 - 2.35 ms
 - 235 ms
 - 0.00235 ms
27. A 12 V pulse is applied to an RC integrator. The pulse width equals one time constant. What will the voltage across the capacitor be at the end of the pulse?
- 4.41 V
 - 12 V
 - 7.58 V
 - 0 V
28. An RC integrator circuit uses a $0.05 \text{ }\mu\text{F}$ capacitor and a $22 \text{ k}\Omega$ resistor. A single pulse of 12 V is applied to the circuit. The pulse width is 2.2 ms. Determine the capacitor voltage at the end of the pulse.
- 10.38 V
 - 12 V
 - 7.58 V
 - 4.42 V
29. An RC integrator uses a $47 \text{ }\mu\text{F}$ capacitor and a $12 \text{ k}\Omega$ resistor. A square wave input with a frequency of 200 kHz is applied. The approximate output of the circuit is
- a square wave with a frequency of 100 kHz.
 - 0 V.
 - a square wave with a frequency of 200 kHz.
 - a near dc voltage of about half the peak square wave voltage.

Chapter 15: Pulse Response of RC and RL Circuits

30. An RL integrator circuit uses a 10 mH inductor and a 10 Ω resistor. A pulse with a peak voltage of 16 V is applied for 1 ms. What is the output voltage?
 - a. 10.11 V
 - b. 13.84 V
 - c. 15.2 V
 - d. 16.32 V
31. When a 10 V pulse with a width equal to one time constant is applied to an RC integrator, the capacitor charges to
 - a. 10 V
 - b. 5 V
 - c. 6.3 V
 - d. 3.7 V
32. When a 10 V pulse with a width equal to one time constant is applied to an RC differentiator, the capacitor charges to
 - a. 10 V
 - b. 5 V
 - c. 6.3 V
 - d. 3.7 V
33. In an RC integrator, the output pulse closely resembles the input pulse when
 - a. τ is much larger than the pulse width.
 - b. τ is equal to the pulse width.
 - c. τ is less than the pulse width.
 - d. τ is much less than the pulse width.
34. In an RC differentiator, the output pulse closely resembles the input pulse when
 - a. τ is much larger than the pulse width.
 - b. τ is equal to the pulse width.
 - c. τ is less than the pulse width.
 - d. τ is much less than the pulse width.
35. If you have an RC and an RL differentiator with equal time constants sitting side-by-side and you apply the same pulse to both,
 - a. the RC has the widest output pulse.
 - b. the RL has the most narrow spikes on the output.
 - c. the output of one is an increasing exponential and the output of the other is a decreasing exponential.
 - d. you can't tell the difference by observing the output waveforms.

APPENDIX E: POSTTEST (QUIZZES)

CHAPTER 3 QUIZ

Student Name _____

1. Voltage and resistance are inversely proportional.
 - a. true
 - b. false
2. A circuit consists of a voltage of 12 V and a resistance of 47 Ω . The circuit's current is 0.255 A.
 - a. true
 - b. false
3. A circuit consists of a voltage of 12 V and a resistance of 47 Ω . The power dissipated by the resistor is 30.6 W.
 - a. true
 - b. false
4. If the resistance in a circuit decreases, then the current will increase.
 - a. true
 - b. false
5. A 47 Ω resistor has 0.5 mA flowing through it. It is ok to use a resistor with a power rating of 0.25 W.
 - a. true
 - b. false
6. Resistance and current are
 - a. directly proportional.
 - b. inversely proportional.
 - c. not related.
 - d. are similar to voltage.
7. If the voltage across a circuit decreases, then
 - a. the current will increase.
 - b. the resistance will decrease.
 - c. the resistance will increase.
 - d. the current will decrease.

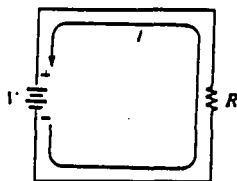


FIGURE 3-2

8. See Figure 3-2. If $V = 12\text{ V}$ and $R = 12\text{ k}\Omega$, then $I =$
 - a. 0.001 mA
 - b. 0.01 mA
 - c. 0.1 mA
 - d. 1 mA
 - e. 10 mA
9. See Figure 3-2. If $I = 32\text{ mA}$ and $R = 0.469\text{ k}\Omega$, then $V =$
 - a. 12 V
 - b. 15 V
 - c. 19 V
 - d. 22 V
10. See Figure 3-2. If $V = 67\text{ V}$ and $I = 47\text{ mA}$, then $R =$
 - a. $1.425\text{ k}\Omega$
 - b. $1.67\text{ k}\Omega$
 - c. $0.70\text{ k}\Omega$
 - d. $3.15\text{ }\Omega$
11. See Figure 3-2. If $V = 12\text{ V}$ and $R = 12\text{ k}\Omega$ and the resistor opens, the current will be
 - a. 1 mA
 - b. hard to determine.
 - c. 0
 - d. 10 mA
12. See Figure 3-2. If the voltage is increased in 1-V steps,
 - a. the current will decrease in steps.
 - b. the resistance will decrease in steps.
 - c. the current will increase in steps.
 - d. the resistance and current will not change.
13. See Figure 3-2. If $V = 50\text{ V}$ and $I = 0.5\text{ mA}$, then the power dissipated by the resistor is
 - a. 25 W
 - b. 2.5 W
 - c. 0.25 W
 - d. 25 mW

14. See Figure 3-2. If $V = 50\text{ V}$ and $I = 5\text{ A}$, then the resistor must be capable of dissipating
- 250 W
 - 10 W
 - 1 W
 - 250 mW
15. A circuit consisting of a resistor color coded red, red, red is placed across a source of 12 V. What value resistor and wattage rating could be used?
- 22,000 Ω at 1/4 W
 - 2200 Ω at 1/2 W
 - 22 k Ω at 1/4 W
 - 220 Ω at 1/8 W
16. Which of the following terms is not a resistor rating?
- resistor value in ohms
 - resistor tolerance
 - current
 - power rating
17. See Figure 3-2. $V = 12\text{ V}$ and R has the color codes brown, black, orange. You measure the current in the circuit. What limits of current might you expect to measure?
- 1.2 mA and 1.4 mA
 - 1 mA and 1.6 mA
 - 0.8 mA and 1.2 mA
 - 1 mA and 1.5 mA
18. See Figure 3-2. The resistor is very hot to touch. What should you do to remedy the problem? The current is correct.
- Increase the voltage.
 - Put in a resistor with a smaller value.
 - Replace the resistor with one of a larger power rating.
 - Wait for it to burn out and then fix it.
19. A 40-W lightbulb has a resistance measurement of 24 Ω when out of the circuit. What is the resistance of the bulb when it is hot and in a circuit with a supply of 120 V?
- 180 Ω
 - 0.003 Ω
 - 360 Ω
 - 1200 Ω
20. See Figure 3-2. If the resistor develops an open,
- the power dissipated will increase
 - the circuit current will decrease.
 - the source voltage will decrease to zero.
 - the resistance will decrease.

CHAPTER 4 QUIZ

Student Name _____

1. In a series circuit, the sum of the individual resistor currents equals the total current.
 - a. true
 - b. false
2. The sum of the individual voltage drops in a series circuit equals the source voltage. This is Kirchhoff's voltage law.
 - a. true
 - b. false
3. The total power used in a series circuit is the product of each individual resistor's power.
 - a. true
 - b. false
4. Three resistors, 4.7 k Ω , 1.2 k Ω , and 3.3 k Ω are in series. The total resistance is 9200 Ω .
 - a. true
 - b. false
5. A 1/2-W resistor can safely dissipate more than 1/2 W.
 - a. true
 - b. false

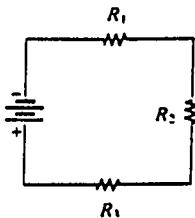


FIGURE 4-1

6. See Figure 4-1. $R_1 = 12$ k Ω , $R_2 = 4.7$ k Ω , and $R_3 = 2.2$ k Ω .
 $R_T =$
 - a. 19.8 k Ω
 - b. 18.9 k Ω
 - c. 8.6 k Ω
 - d. 1.33 k Ω
7. See Figure 4-1. If R_3 opens and the source voltage is 12 V, the current is
 - a. 12 V
 - b. maximum.
 - c. 0
 - d. unable to be determined.

8. See Figure 4-1. $R_1 = 12\text{ k}\Omega$, $R_2 = 4.7\text{ k}\Omega$, $R_3 = 2.2\text{ k}\Omega$, and $V_s = 50\text{ V}$. The current is
- 26.5 mA
 - 378 mA
 - 0
 - 2.65 mA
9. Refer to problem 8. V_{R1} is
- 31.8 V
 - 63.6 V
 - 5.8 V
 - 12.4 V
10. Refer to problem 8. V_{R2} is
- 16.4 V
 - 31.8 V
 - 12.4 V
 - 5.8 V
11. Refer to problem 8. If R_2 shorts, the voltage drop across R_1 will
- increase
 - decrease
 - remain the same
12. Refer to problem 8. If R_3 opens, the voltage drop across R_2 will be
- 16.5 V
 - 33.5 V
 - 9 V
 - 0 V
13. Refer to problem 8. The total power dissipated in the circuit is
- 132.5 mW
 - 132.5 W
 - 84 mW
 - 33 mW
14. Refer to problem 8. If R_1 is shorted out, the total power dissipated by the circuit will
- increase
 - decrease
 - remain the same
15. Two power supplies are in series with voltages of 12 V and 17 V respectively. What is the total supply voltage?
- 5 V
 - 5 V
 - 29 V
 - 29 V
16. Two resistors are in series across a source of 20 V. Each resistor has a value of 100 k Ω . What is the voltage across each resistor?
- 20 V
 - 10 V
 - 100 mA
 - 100 k Ω

17. A two-resistor voltage divider has $R_1 = 22 \text{ k}\Omega$ and $R_2 = 12 \text{ k}\Omega$ across 47 V. What is the voltage across R_2 ?
- a. about 16.6 V
 - b. about 30.4 V
 - c. about 25.6 V
 - d. about 17.2 V
18. A 500 k Ω pot is connected across 5 V. The voltage from the wiper to the lower end of the pot is 1.2 V. What is the resistance of the lower part of the pot?
- a. 380 k Ω
 - b. 120 k Ω
 - c. 500 k Ω
 - d. 0 Ω
19. Three batteries are in series with potentials of 1.2 V, 5 V, and 6 V, but the 1.2-V battery is opposing the other two. The total supply voltage is
- a. 12.2 V
 - b. 9.8 V
 - c. 1.2 V
 - d. 1.3 V
20. Three sources are connected in series aiding. Each has a potential of 8 V. What is the total circuit voltage?
- a. 32 V
 - b. 24 V
 - c. 16 V
 - d. 8 V

CHAPTER 5 QUIZ

Student Name _____

1. Four resistors are connected in parallel. The voltage across one resistor is 14 V. The voltage across the other resistors will also be 14 V.
 - a. true
 - b. false
 2. The sum of the values of four resistors in parallel equals the total resistance.
 - a. true
 - b. false
 3. A parallel branch has 1.2 mA flowing. The other branch has 3.4 mA. The total current into the junction of these branches is 4.6 mA.
 - a. true
 - b. false
 4. If an open occurs in one branch of a parallel circuit, then the total current will increase.
 - a. true
 - b. false
 5. The total power dissipated in a parallel circuit is the sum of the individual powers.
 - a. true
 - b. false
 6. A circuit of three parallel resistors, 1.2 k Ω , 4.7 k Ω , and 6.8 k Ω is supplied with a 20-V source. What is the total resistance?
 - a. 838 Ω
 - b. 1200 Ω
 - c. 4700 Ω
 - d. 6800 Ω
 - e. 12,700 Ω
 7. Refer to the values of problem 6. The current through the 4.7-k Ω resistor is
 - a. 16.7 mA
 - b. 4.25 mA
 - c. 2.94 mA
 - d. 1.57 mA
-

8. Two resistors are in parallel, $1500\ \Omega$ and $5000\ \Omega$. The total resistance of the circuit is
- $1500\ \Omega$
 - $5000\ \Omega$
 - greater than $5000\ \Omega$
 - less than $1500\ \Omega$
9. A parallel circuit consisting of $R_1 = 100\ \Omega$, $R_2 = 500\ \Omega$, and R_3 has an $R_T = 76.92\ \Omega$. Find the value of R_3 .
- $140\ \Omega$
 - $1000\ \Omega$
 - $1850\ \Omega$
 - There is not enough data to compute.
10. A parallel circuit consists of $R_1 = 1.2\ \text{k}\Omega$ in parallel with R_2 . $I_T = 5\ \mu\text{A}$ and $I_2 = 3\ \mu\text{A}$. What is the value of V_{R_1} ?
- $6\ \text{mV}$
 - $18\ \text{mV}$
 - $3.6\ \text{mV}$
 - $2.4\ \text{mV}$
11. Three resistors are connected in parallel across $50\ \text{V}$. The values are $680\ \text{k}\Omega$, $0.047\ \text{M}\Omega$ and $470\ \text{k}\Omega$. If the $0.047\text{-M}\Omega$ resistor opens, the total current, I_T , will be
- $1.2\ \text{mA}$
 - $555\ \mu\text{A}$
 - $180\ \mu\text{A}$
 - $790\ \mu\text{A}$
12. Six $1.2\text{-M}\Omega$ resistors are connected in parallel across $12\ \text{V}$. What is the total resistance of the circuit?
- $1.2\ \text{M}\Omega$
 - $250\ \text{k}\Omega$
 - $200\ \text{k}\Omega$
 - $120\ \text{k}\Omega$
13. Three parallel branches have a total current of $45\ \mu\text{A}$ flowing into them. $I_1 = 15\ \mu\text{A}$ and $I_2 = 19\ \mu\text{A}$. Find the current in the third branch.
- $34\ \mu\text{A}$
 - $26\ \mu\text{A}$
 - $30\ \mu\text{A}$
 - $11\ \mu\text{A}$
14. As resistors are added in parallel to a circuit,
- I_T decreases and R_T increases.
 - I_T decreases and R_T decreases.
 - I_T increases and R_T decreases.
 - I_T increases and R_T increases.

15. If a resistor in parallel opens, the total current will
a. increase and the voltage will decrease.
b. decrease and the voltage will be constant.
c. increase and the fuse will blow.
d. decrease and the voltage will increase.
16. The total power in a parallel circuit
a. is the sum of the individual powers.
b. is found by V_T/I_T
c. is the sum of the individual powers minus the total power.
d. is found by $I_T^2 R_T$.
17. A circuit consists of three resistors in parallel, $R_1 = 4.7 \text{ k}\Omega$, $R_2 = 3.3 \text{ k}\Omega$, and R_3 . $I_T = 35 \text{ mA}$ and $V_S = 50 \text{ V}$. Find I_{R_3} .
a. 10.64 mA
b. 15.15 mA
c. 9.21 mA
d. 4.72 mA
18. 680 mA flow into four parallel resistors. The currents through three of the resistors are 95 mA, 400 mA, 19 mA. The current through the fourth resistor is
a. 585 mA
b. 280 mA
c. 261 mA
d. 166 mA
19. Two resistors are in parallel. $R_1 = 470 \text{ }\Omega$ and $R_T = 330 \text{ }\Omega$. Find the value of R_2 .
a. 770 Ω
b. 1108 Ω
c. 194 Ω
d. 110 Ω
20. House wiring of lamps are usually in parallel
a. so they will draw less current.
b. because the resistance is higher.
c. so one lamp burnout will not affect the other lamps.
d. because the power is greater than in a series circuit.

CHAPTER 5 QUIZ

Student Name _____

1. Four resistors are connected in parallel. The voltage across one resistor is 14 V. The voltage across the other resistors will also be 14 V.
 - a. true
 - b. false
 2. The sum of the values of four resistors in parallel equals the total resistance.
 - a. true
 - b. false
 3. A parallel branch has 1.2 mA flowing. The other branch has 3.4 mA. The total current into the junction of these branches is 4.6 mA.
 - a. true
 - b. false
 4. If an open occurs in one branch of a parallel circuit, then the total current will increase.
 - a. true
 - b. false
 5. The total power dissipated in a parallel circuit is the sum of the individual powers.
 - a. true
 - b. false
 6. A circuit of three parallel resistors, 1.2 k Ω , 4.7 k Ω , and 6.8 k Ω is supplied with a 20-V source. What is the total resistance?
 - a. 838 Ω
 - b. 1200 Ω
 - c. 4700 Ω
 - d. 6800 Ω
 - e. 12,700 Ω
 7. Refer to the values of problem 6. The current through the 4.7-k Ω resistor is
 - a. 16.7 mA
 - b. 4.25 mA
 - c. 2.94 mA
 - d. 1.57 mA
-

8. Two resistors are in parallel, $1500\ \Omega$ and $5000\ \Omega$. The total resistance of the circuit is
- $1500\ \Omega$
 - $5000\ \Omega$
 - greater than $5000\ \Omega$
 - less than $1500\ \Omega$
9. A parallel circuit consisting of $R_1 = 100\ \Omega$, $R_2 = 500\ \Omega$, and R_3 has an $R_T = 76.92\ \Omega$. Find the value of R_3 .
- $140\ \Omega$
 - $1000\ \Omega$
 - $1850\ \Omega$
 - There is not enough data to compute.
10. A parallel circuit consists of $R_1 = 1.2\ \text{k}\Omega$ in parallel with R_2 . $I_T = 5\ \mu\text{A}$ and $I_2 = 3\ \mu\text{A}$. What is the value of V_{R_1} ?
- $6\ \text{mV}$
 - $18\ \text{mV}$
 - $3.6\ \text{mV}$
 - $2.4\ \text{mV}$
11. Three resistors are connected in parallel across $50\ \text{V}$. The values are $680\ \text{k}\Omega$, $0.047\ \text{M}\Omega$ and $470\ \text{k}\Omega$. If the $0.047\text{-M}\Omega$ resistor opens, the total current, I_T , will be
- $1.2\ \text{mA}$
 - $555\ \mu\text{A}$
 - $180\ \mu\text{A}$
 - $790\ \mu\text{A}$
12. Six $1.2\text{-M}\Omega$ resistors are connected in parallel across $12\ \text{V}$. What is the total resistance of the circuit?
- $1.2\ \text{M}\Omega$
 - $250\ \text{k}\Omega$
 - $200\ \text{k}\Omega$
 - $120\ \text{k}\Omega$
13. Three parallel branches have a total current of $45\ \mu\text{A}$ flowing into them. $I_1 = 15\ \mu\text{A}$ and $I_2 = 19\ \mu\text{A}$. Find the current in the third branch.
- $34\ \mu\text{A}$
 - $26\ \mu\text{A}$
 - $30\ \mu\text{A}$
 - $11\ \mu\text{A}$
14. As resistors are added in parallel to a circuit,
- I_T decreases and R_T increases.
 - I_T decreases and R_T decreases.
 - I_T increases and R_T decreases.
 - I_T increases and R_T increases.

15. If a resistor in parallel opens, the total current will
- increase and the voltage will decrease.
 - decrease and the voltage will be constant.
 - increase and the fuse will blow.
 - decrease and the voltage will increase.
16. The total power in a parallel circuit
- is the sum of the individual powers.
 - is found by V_T/I_T .
 - is the sum of the individual powers minus the total power.
 - is found by $I_1^2 R_1$.
17. A circuit consists of three resistors in parallel, $R_1 = 4.7 \text{ k}\Omega$, $R_2 = 3.3 \text{ k}\Omega$, and R_3 . $I_T = 35 \text{ mA}$ and $V_S = 50 \text{ V}$. Find I_{R_3} .
- 10.64 mA
 - 15.15 mA
 - 9.21 mA
 - 4.72 mA
18. 680 mA flow into four parallel resistors. The currents through three of the resistors are 95 mA, 400 mA, 19 mA. The current through the fourth resistor is
- 585 mA
 - 280 mA
 - 261 mA
 - 166 mA
19. Two resistors are in parallel. $R_1 = 470 \text{ }\Omega$ and $R_T = 330 \text{ }\Omega$. Find the value of R_2 .
- 770 Ω
 - 1108 Ω
 - 194 Ω
 - 110 Ω
20. House wiring of lamps are usually in parallel
- so they will draw less current.
 - because the resistance is higher.
 - so one lamp burnout will not affect the other lamps.
 - because the power is greater than in a series circuit.

CHAPTER 6 QUIZ

Student Name _____

1. To avoid loading effects, a voltmeter should have a low internal resistance.
 - a. true
 - b. false

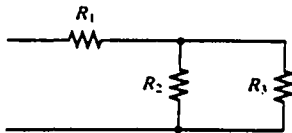


FIGURE 6-1

2. See Figure 6-1. R_1 is in series with R_2 .
 - a. true
 - b. false
3. See Figure 6-1. R_1 is in series with the parallel combination R_2 and R_3 .
 - a. true
 - b. false
4. Resistors are in parallel if they share the same current.
 - a. true
 - b. false
5. In a combination circuit, the total resistance can be represented by one resistor of the correct value.
 - a. true
 - b. false
6. See Figure 6-1. Resistor R_1 is connected
 - a. in series with R_2 .
 - b. in series with R_3 .
 - c. in parallel with R_2 .
 - d. in parallel with R_3 .
 - e. None of these.
7. See Figure 6-2. R_1 and R_4 are connected
 - a. in series with each other and R_3 .
 - b. in series with each other, R_2 , and R_3 .
 - c. in series with each other.
 - d. in parallel with R_3 .

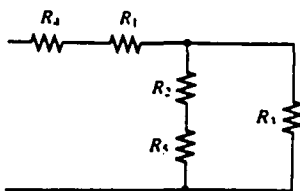


FIGURE 6-2

8. See Figure 6-2. R_2 and R_3 are connected
 - a. in series with each other and in parallel with R_5 .
 - b. in parallel.
 - c. in series with R_1 .
 - d. in series with R_4 .
9. See Figure 6-1. If $R_1 = 4.7 \text{ k}\Omega$, $R_2 = 3300 \Omega$, and $R_3 = 1000 \Omega$, the total resistance of the circuit is
 - a. 5700Ω
 - b. 5467Ω
 - c. 4125Ω
 - d. 660Ω
10. See Figure 6-1 and the values in problem 9. If the source voltage is 50 V , calculate the total current.
 - a. 8.8 mA
 - b. 9.15 mA
 - c. 12.1 mA
 - d. 75.7 mA
11. Refer to problem 10. The voltage drop across R_3 is
 - a. 42.9 V
 - b. 5.62 V
 - c. 7.01 V
 - d. 1.76 V
12. See Figure 6-2. If all of the resistors are $33 \text{ k}\Omega$, the total resistance is
 - a. $165 \text{ k}\Omega$
 - b. $55 \text{ k}\Omega$
 - c. $116.5 \text{ k}\Omega$
 - d. $88 \text{ k}\Omega$
13. See Figure 6-2. If all of the resistors are 1000Ω and the source voltage is 25 V , the voltage drop across R_3 is
 - a. 6.25 V
 - b. 43.75 V
 - c. 18.75 V
 - d. 25 V

14. See Figure 6-1. If another resistor is placed in parallel with R_3 ,
- V_{R1} will decrease.
 - V_{R2} will decrease.
 - I_1 will decrease.
 - I_2 will increase.

15. See Figure 6-3. If $V_{R2} = 12\text{ V}$, find V_{DE} .
- 12 V
 - 12 V
 - 24 V
 - 36 V

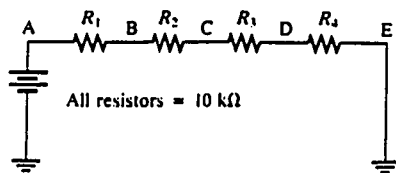


FIGURE 6-3

16. See Figure 6-3. If $V_D = 9.6\text{ V}$, find V_{DB} .
- 9.6 V
 - 4.8 V
 - 19.2 V
 - 19.2 V
17. See Figure 6-2. If R_2 shorts, I_3 will
- increase.
 - decrease.
 - remain the same.
18. See Figure 6-2. If R_3 opens, V_{R4} will
- increase.
 - decrease.
 - remain the same.
19. See Figure 6-2. If R_4 shorts, V_{R3} will
- increase.
 - decrease.
 - remain the same.
20. If a combination of four parallel 10-kΩ resistors were in series with a single 20-kΩ resistor, and one of the parallel combination resistors opened, the voltage across the other parallel resistors would
- increase.
 - decrease.
 - remain the same.

CHAPTER 8 QUIZ

Student Name _____

1. The period of a sine wave is the reciprocal of the frequency.
 - a. true
 - b. false
2. The higher the frequency of a sine wave, the longer the period.
 - a. true
 - b. false
3. The peak value of a sine wave is larger in value than the rms value.
 - a. true
 - b. false
4. If an ac voltage is applied to a resistor, the current decreases as the voltage increases.
 - a. true
 - b. false
5. Sine, square, and triangle waves are all forms of ac waves.
 - a. true
 - b. false
6. The formula for V_{rms} for a sine wave is
 - a. $V_{p-p} \times 0.707$
 - b. $V_p \times 0.707$
 - c. $V_p \times 1.414$
 - d. $V_{p-p} \times 1.414$
7. The rms value of a sine wave voltage means
 - a. the heating effect of a battery of the same voltage.
 - b. the root mean square value.
 - c. $I_{rms} \times R$.
 - d. all of these.
8. A sine wave has a peak value of 169 V. What is the instantaneous value at an angle of 37° ?
 - a. 135 V
 - b. 119 V
 - c. 239 V
 - d. 102 V

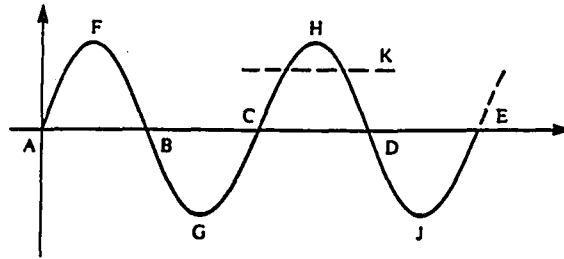


FIGURE 8-1

9. See Figure 8-1. The figure shows
 - a. four complete cycles.
 - b. four positive and four negative alternations.
 - c. two complete cycles.
 - d. four positive alternations.
 - e. four negative alternations.
10. The number of cycles occurring in one second is called
 - a. an alternation.
 - b. revolutions per minute.
 - c. alternating current.
 - d. the frequency.
11. See Figure 8-1. The time from point B to point C is called
 - a. an alternation.
 - b. a cycle.
 - c. the period.
 - d. peak voltage.
12. See Figure 8-1. The voltage value at point H represents
 - a. rms voltage.
 - b. p-p voltage.
 - c. peak voltage.
 - d. one cycle of voltage.
13. See Figure 8-1. The rms voltage is seen at point
 - a. J
 - b. K
 - c. F
 - d. E
14. See Figure 8-1. The time from points G to J is known as
 - a. one cycle.
 - b. one alternation.
 - c. the rms value.
 - d. V_p .

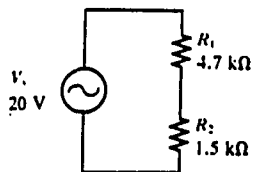


FIGURE 8-2

15. See Figure 8-2. Find V_{R1} .
 - a. 15.16 V_p
 - b. 42.88 V_p
 - c. 21.43 V_p
 - d. 15.16 V_p
16. See Figure 8-2. Find I_{p-p} .
 - a. 4.55 mA
 - b. 3.22 mA
 - c. 9.12 mA
 - d. 6.44 mA
17. See Figure 8-2. Find $V_{R2,p-p}$.
 - a. 4.84 V
 - b. 9.68 V
 - c. 13.68 V
 - d. 6.84 V
18. The correct formula for finding the period (T) of a sine wave is
 - a. $T = 1/f$
 - b. $f = 1/T$
 - c. $T = 0.707f$
 - d. $T = 1.414f$
19. Your scope is set up to measure a voltage, but the trace is a straight horizontal line. The problem could be
 - a. there is no voltage to the circuit.
 - b. the scope is connected to ground.
 - c. the input scope switch is set to the ground position.
 - d. any of these.
20. A square wave consists of
 - a. a fundamental and even harmonics.
 - b. a fundamental and all harmonics.
 - c. a fundamental and odd harmonics.
 - d. even and odd harmonics only.

CHAPTER 9 QUIZ

Student Name _____

1. The measure of a capacitor's ability to store charge is called capacitance.
 - a. true
 - b. false
2. A capacitor blocks ac and passes dc.
 - a. true
 - b. false
3. If two capacitors are in series across a dc source, the largest capacitor has the largest voltage across it.
 - a. true
 - b. false
4. If the area of the plates of a capacitor is increased, the capacitance increases.
 - a. true
 - b. false
5. The time required for a capacitor to charge by 63.2% is called the time constant.
 - a. true
 - b. false
6. A capacitor has a charge of $2500\ \mu\text{C}$ and a voltage across it of 25 V. The capacitance is
 - a. $0.01\ \mu\text{F}$
 - b. $0.1\ \mu\text{F}$
 - c. $10\ \mu\text{F}$
 - d. $100\ \mu\text{F}$
7. A $4.7\text{-}\mu\text{F}$ capacitor has a voltage across it of 50 V. What charge is stored in the capacitor?
 - a. $235\ \mu\text{C}$
 - b. $470\ \mu\text{C}$
 - c. $23.5\ \mu\text{C}$
 - d. $2.35\ \mu\text{C}$
8. The dc working voltage of a capacitor is 100 V. This means that the dielectric must be able to withstand
 - a. 100 V dc
 - b. $100\ \text{V}_{\text{peak}}$
 - c. $200\ \text{V}_{\text{p-p}}$
 - d. all of the above

9. Two equal value capacitors of $200\ \mu\text{F}$ each are in parallel across $50\ \text{V}$. What is C_T and the voltage across each capacitor?
- $100\ \mu\text{F}$ and $25\ \text{V}$
 - $400\ \mu\text{F}$ and $50\ \text{V}$
 - $400\ \mu\text{F}$ and $25\ \text{V}$
 - $200\ \mu\text{F}$ and $50\ \text{V}$
10. Three capacitors are in series. $C_1 = 100\ \mu\text{F}$, $C_2 = 100\ \mu\text{F}$, and $C_3 = 50\ \mu\text{F}$. The source voltage is $75\ \text{V}$. What is the voltage across C_3 ?
- $18.75\ \text{V}$
 - $50\ \text{V}$
 - $37.5\ \text{V}$
 - $100\ \text{V}$
11. A $0.001\text{-}\mu\text{F}$ capacitor is in series with a $10\text{-k}\Omega$ resistor. What is the circuit's time constant?
- $10\ \mu\text{s}$
 - $100\ \mu\text{s}$
 - $0.1\ \text{s}$
 - $1\ \text{s}$
12. A $0.047\text{-}\mu\text{F}$ capacitor is in series with a $1\text{-M}\Omega$ resistor. How long will it take to completely charge the capacitor? The supply voltage is $50\ \text{V}$.
- $0.047\ \text{s}$
 - $0.029\ \text{s}$
 - $0.235\ \text{s}$
 - $0.47\ \text{s}$
13. A $100\ \mu\text{F}$ -capacitor is charged to $25\ \text{V}$. You attempt to discharge the capacitor through a $22\text{-k}\Omega$ resistor. How long will it take to completely discharge?
- $2.2\ \text{s}$
 - $4.4\ \text{s}$
 - $11\ \text{s}$
 - $132\ \text{s}$
14. A $0.01\text{-}\mu\text{F}$ capacitor is in series with a $2.2\text{-k}\Omega$ resistor. A voltage of $30\ \text{V}$ is applied when a switch is closed. What will the voltage across the capacitor be after one time constant?
- $29.4\ \text{V}$
 - $28.50\ \text{V}$
 - $25.95\ \text{V}$
 - $18.96\ \text{V}$

15. A $2.2\text{-}\mu\text{F}$ capacitor with a 1-kHz ac voltage applied to it will have _____ X_c .
a. infinite
b. zero
c. $72.4\ \Omega$
d. $0.013\ \Omega$
16. A 159-pF capacitor has an X_c of $502\ \Omega$. What is the operating frequency?
a. 2 kHz
b. 20 kHz
c. 200 kHz
d. 2000 kHz
17. An ohmmeter is used to test the resistance of a capacitor. The reading in both directions is $0\ \Omega$. The capacitor is probably
a. open.
b. shorted.
c. leaking.
d. completely charged.
18. If the frequency applied to a capacitor is increased, the capacitive reactance will
a. increase.
b. decrease.
c. remain the same.
d. vary up and down.
19. A $47\text{-}\mu\text{F}$ capacitor is connected to a 5-V 400-Hz source. The current will be
a. 590 mA
b. 1.69 mA
c. 94 mA
d. 188 mA
20. A capacitor that will transfer an ac signal from one stage to another is called
a. a bypass capacitor.
b. a filter capacitor.
c. a coupling capacitor.
d. a transfer capacitor.

CHAPTER 10 QUIZ

Student Name _____

1. The total inductance of series inductors is the sum of all the inductances.
 - a. true
 - b. false
 2. The energy stored in an inductor's electrostatic field is produced by the current.
 - a. true
 - b. false
 3. An inductor passes ac and opposes dc.
 - a. true
 - b. false
 4. Inductive reactance increases when the frequency is increased.
 - a. true
 - b. false
 5. In an inductive circuit, the current leads the voltage.
 - a. true
 - b. false
 6. Two 2.5-mH inductors are in series with a 4.7-k Ω resistor. The source voltage is 100 V. What is the maximum current in this circuit?
 - a. 21.3 mA
 - b. 63.2 mA
 - c. 1.1 mA
 - d. 7.9 mA
 7. An inductor has a dc current flowing through it. The magnetic field
 - a. is changing constantly.
 - b. is collapsing.
 - c. is said to move from south to north.
 - d. is said to move from north to south.
 8. If a coil of wire is wound on an iron rod, the magnetic field
 - a. is weaker than if a paper tube were used as the core.
 - b. is weaker than if the core were air.
 - c. is stronger than a coil wound on a paper tube.
 - d. will collapse.
-

9. A frequency of 10 kHz is applied to a coil with an inductance of 150 mH. What is the inductive reactance?
- 1500 Ω
 - 6280 Ω
 - 8450 Ω
 - 9420 Ω
10. In an inductive circuit, the _____ leads the _____.
- voltage, power
 - current, voltage
 - voltage, current
 - power, current
11. As frequency is increased, X_L
- increases
 - decreases
 - remains the same
 - changes up and down
12. A 50-mH inductor has an X_L of 5000 Ω . What is the applied frequency?
- 159 Hz
 - 1590 Hz
 - 15,923 Hz
 - 159,235 Hz
13. A 50-mH inductor is in series with a 5-k Ω resistor. What is the time constant?
- 10 μ s
 - 100 s
 - 250 s
 - 10 ms
14. How many time constants does it take to completely build up a magnetic field around an inductor?
- one
 - two
 - four
 - five
15. A series inductor with an inductance of 10 mH and a winding resistance of 50 Ω is applied to a 500-Hz source. What is the inductive reactance?
- 0.032 Ω
 - 31.4 Ω
 - 0.5 Ω
 - 31.4 k Ω

16. A 40-mH inductor is in parallel with a 24-mH inductor. The total inductance is
 - a. 64 mH
 - b. 32 mH
 - c. 15 mH
 - d. 15.39 mH
17. You think that an inductor is faulty. You measure the resistance at 0 Ω . The dc voltage across the coil measures zero. The probable fault, if any, is
 - a. the coil is shorted.
 - b. the coil is open.
 - c. the coil is normal.
 - d. the coil will work on ac.
18. An inductor is placed in an ac circuit with a voltage of 20 V. The current is 250 mA. What is the inductive reactance?
 - a. 0.0125 Ω
 - b. 160 Ω
 - c. 80 Ω
 - d. Cannot be computed since no frequency is given
19. If 50 V at a frequency of 5 kHz were measured across an inductor with an inductance of 500 mH, what would be the current?
 - a. 6.36 mA
 - b. 3.18 mA
 - c. 1.59 mA
 - d. 0.08 mA
20. A coil of wire is carrying a dc current of 50 mA. The X_L of the coil at 60 Hz is 400 Ω . The voltage across the coil is 25 V. What is the resistance of the coil?
 - a. 500 Ω
 - b. 400 Ω
 - c. 16 Ω
 - d. 20 Ω

CHAPTER 11 QUIZ

Student Name _____

1. The number of turns in the primary and secondary determines the turns ratio.
 - a. true
 - b. false
2. Maximum power is moved from the secondary to the primary when the source resistance is equal to the load resistance.
 - a. true
 - b. false
3. A transformer with a turns ratio of 0.5 is a step-up transformer.
 - a. true
 - b. false
4. The core materials of transformers are often laminated iron or air.
 - a. true
 - b. false
5. Transformers are efficient devices.
 - a. true
 - b. false
6. A step-down transformer will decrease _____ and increase _____.
 - a. resistance, power
 - b. current, voltage
 - c. voltage, current
 - d. power, current
7. The loss in a transformer due to the changing magnetic field is called
 - a. eddy current loss.
 - b. hysteresis loss.
 - c. I^2R loss.
 - d. flux leakage loss.
8. A step-up transformer will increase _____ and decrease _____.
 - a. voltage, impedance
 - b. voltage, power
 - c. current, impedance
 - d. power, current

9. The loss in a transformer due to currents flowing in the core is called
 - a. hysteresis loss.
 - b. winding loss.
 - c. flux leakage loss.
 - d. eddy current loss.
10. To transfer the most power from the source to the load,
 - a. the source resistance must be larger than the load resistance.
 - b. the load resistance must equal the power loss.
 - c. the source resistance must equal the load resistance.
 - d. the power in the primary and secondary must be equal.

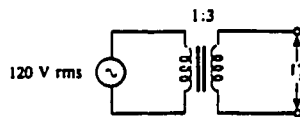


FIGURE 11-1

11. See Figure 11-1. There are five times as many turns in the secondary as the primary. What is the secondary voltage, V_s ?
 - a. 24 V
 - b. 240 V
 - c. 560 V
 - d. 600 V
12. See Figure 11-1. If the ratio of primary-to-secondary turns is 4.5:1, what is the output voltage, V_s ?
 - a. 540 V
 - b. 26.67 V
 - c. 5.92 V
 - d. 4.72 V
13. See Figure 11-1. If the primary-to-secondary turns ratio is 4:1, and a load resistor of $50\ \Omega$ is in the secondary, what is the secondary current?
 - a. 1.66 A
 - b. 600 mA
 - c. 9.6 A
 - d. 4.8 A
14. See Figure 11-1. The primary-to-secondary turns ratio is 4:1 and $I_s = 40\text{ mA}$. What is the primary current?
 - a. 160 mA
 - b. 40 mA
 - c. 10 mA
 - d. 4 mA

15. See Figure 11-1. The primary-to-secondary turns ratio is 4:1 and $I_p = 40$ mA. What is the reflected resistance seen by the primary?
- 4 k Ω
 - 8 k Ω
 - 12 k Ω
 - 16 k Ω
16. What ratio would transform 100 V into 40 V?
- 40:100
 - 4:1
 - 400:1000
 - 2.5:1
17. The primary-to-secondary turns ratio is 60:5 and the primary voltage and current is 120 V and 75 mA. What is the primary power?
- 0.75 W
 - 1.25 W
 - 9 W
 - 9.6 W
18. A transformer measures full voltage across the primary terminals but there is no voltage delivered to the load. The trouble might be
- a short across the secondary.
 - an open primary.
 - a shorted primary.
 - an open transformer core.
19. You desire to match a 300-ohm load to a 75-ohm source. What would be the primary-to-secondary turns ratio of the transformer? -
- 1:2
 - 2:1
 - 1:4
 - 4:1
20. You have a need to isolate two circuits with no change of voltage. You would use a/an _____ transformer with a turns ratio of _____.
- step-up, 2:1
 - step-down, 1:1
 - step-up, 1:1
 - isolation, 1:1

CHAPTER 12 QUIZ

Student Name _____

1. When a sine wave is applied to an RC circuit, the current and all the voltage drops are also sine waves.
 - a. true
 - b. false
2. The current in an RC series circuit always lags the source voltage.
 - a. true
 - b. false
3. The phasor combination of true power and reactive power is called apparent power.
 - a. true
 - b. false
4. A filter blocks certain frequencies and passes others.
 - a. true
 - b. false
5. The phase angle of a series RC circuit varies directly with frequency.
 - a. true
 - b. false
6. See Figure 12-1. Calculate for the total impedance.
 - a. $418\ \Omega$
 - b. $520\ \Omega$
 - c. $280\ \Omega$
 - d. $120\ \Omega$

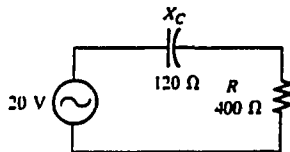


FIGURE 12-1

7. See Figure 12-1. Calculate the phase angle.
 - a. 73.3°
 - b. 17.5°
 - c. 16.7°
 - d. 72.5°

8. See Figure 12-1. Calculate the voltage drop across the capacitor.
- 19.14 V
 - 16.7 V
 - 20 V
 - 5.75 V
9. See Figure 12-1. Calculate the true power.
- 275 mW
 - 916 mW
 - 956 mW
 - 1002 mW
10. See Figure 12-1. Calculate the apparent power.
- 0.874 VA
 - 0.916 VA
 - 0.957 VA
 - 0.989 VA

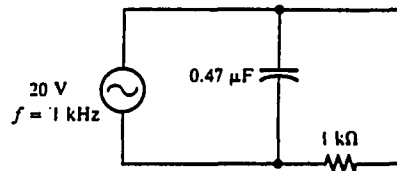


FIGURE 12-2

11. See Figure 12-2. Find the current through the capacitor.
- 20 mA
 - 62 mA
 - 321 mA
 - 59 mA
12. See Figure 12-2. Find the total impedance.
- 1000 Ω
 - 880 Ω
 - 321 Ω
 - 62 Ω
13. See Figure 12-2. Find the phase angle.
- 18.7°
 - 71.3°
 - 14.7°
 - 3.2°

14. See Figure 12-2. Find the apparent power.
 - a. 1.18 VA
 - b. 0.4 VA
 - c. 1.246 VA
 - d. 0.95 VA
15. See Figure 12-2. What is the power factor?
 - a. 0.947
 - b. 0.321
 - c. 0.338
 - d. 2.95
16. See Figure 12-1. If the frequency is increased, the phase angle will _____ and the impedance will _____.
 - a. decrease, increase
 - b. increase, decrease
 - c. decrease, decrease
 - d. increase, increase
17. See Figure 12-2. If the frequency is decreased, the total current will _____ and the total impedance will _____.
 - a. decrease, increase
 - b. increase, decrease
 - c. decrease, decrease
 - d. increase, increase
18. See Figure 12-1. If the output were across the resistor, the circuit would be known as a
 - a. low-pass filter.
 - b. high-pass filter.
 - c. band-pass filter.
 - d. band-reject filter.

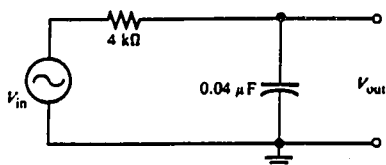


FIGURE 12-3

19. See Figure 12-3. The cutoff frequency is
 - a. 6250 Hz
 - b. 99 Hz
 - c. 480 Hz
 - d. 995 Hz

20. See Figure 12-3. If the input voltage were 17 V, what would the voltage be across the capacitor at the cutoff frequency?
- a. 0 V
 - b. 8 V
 - c. 12 V
 - d. 17 V

CHAPTER 13 QUIZ

Student Name _____

1. Total current in an RL circuit always leads the source voltage.
 - a. true
 - b. false
2. A low-pass filter passes low frequencies and blocks other frequencies.
 - a. true
 - b. false
3. The impedance of an RL circuit varies directly with frequency.
 - a. true
 - b. false
4. In a filter circuit using RL components, an increase in the value of R will increase the cutoff frequency.
 - a. true
 - b. false
5. The impedance of a parallel RL circuit is found by adding X_L to R.
 - a. true
 - b. false

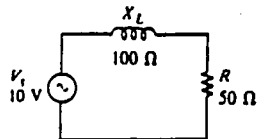


FIGURE 13-1

6. See Figure 13-1. Find the impedance.
 - a. $104\ \Omega$
 - b. $112\ \Omega$
 - c. $1120\ \Omega$
 - d. $1040\ \Omega$
7. See Figure 13-1. Find the phase angle.
 - a. 26.6°
 - b. 0.034°
 - c. 63.4°
 - d. 45°

8. See Figure 13-1. Find the voltage across the inductor.
 a. 0.4 V
 b. 0.894 V
 c. 4.47 V
 d. 8.94 V
9. See Figure 13-1. Find the true power.
 a. 400 mW
 b. 0.894 W
 c. 0.8 W
 d. 112 mW
10. See Figure 13-1. Find the apparent power.
 a. 0.4 VA
 b. 0.8 VA
 c. 8.94 VA
 d. 0.894 VA

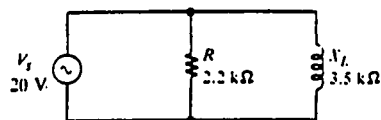


FIGURE 13-2

11. See Figure 13-2. Find the current through the inductor.
 a. 5.71 mA
 b. 0.182 mA
 c. 9.09 mA
 d. 2.15 mA
12. See Figure 13-2. Find the total impedance.
 a. 10.74 k Ω
 b. 9.09 k Ω
 c. 5.71 k Ω
 d. 1.86 k Ω
13. See Figure 13-2. Find the phase angle.
 a. 32.15°
 b. 57.85°
 c. 45°
 d. 53.2°
14. See Figure 13-2. Find the apparent power.
 a. 0.182 VA
 b. 0.532 VA
 c. 1.86 VA
 d. 0.215 VA

15. See Figure 13-2. Find the power factor.
 a. 0.707
 b. 0.846
 c. 0.532
 d. 0.599
16. See Figure 13-1. If the frequency is increased, the phase angle will _____ and the impedance will _____.
 a. decrease, increase
 b. increase, decrease
 c. decrease, decrease
 d. increase, increase
17. See Figure 13-2. If the frequency is decreased, the total current will _____ and the total impedance will _____.
 a. decrease, increase
 b. increase, decrease
 c. decrease, decrease
 d. increase, increase
18. See Figure 13-1. If the output were across the resistor, the circuit would be known as a
 a. low-pass filter.
 b. high-pass filter.
 c. band-pass filter.
 d. band-reject filter.

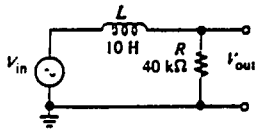


FIGURE 13-3

19. See Figure 13-3. Find the cutoff frequency.
 a. 2.5 MHz
 b. 637 Hz
 c. 1.2 MHz
 d. 408 Hz
20. See Figure 13-3. If the input voltage were 21 V, find the output voltage at the cutoff frequency.
 a. 0 V
 b. 6.15 V
 c. 14.85 V
 d. 21 V

CHAPTER 14 QUIZ

Student Name _____

1. The total reactance of a series RLC circuit at resonance is zero.
 - a. true
 - b. false
2. At resonance, a series RLC circuit is capacitive.
 - a. true
 - b. false
3. If an RLC circuit is resonant, usually $X_L = X_C$.
 - a. true
 - b. false
4. The bandwidth of a resonant circuit varies directly with Q: As Q increases, the bandwidth increases.
 - a. true
 - b. false
5. A parallel resonant circuit has maximum impedance and minimum line current.
 - a. true
 - b. false

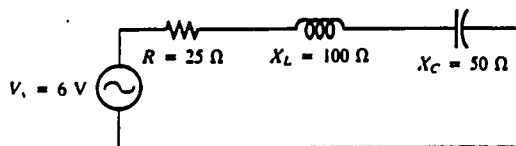


FIGURE 14-1

6. See Figure 14-1. Find the impedance of this circuit.
 - a. 50 Ω
 - b. 75 Ω
 - c. 56 Ω
 - d. 25 Ω
7. See Figure 14-1. If the frequency of the source voltage is decreased a little, the impedance will _____ and the phase angle will _____.
 - a. increase, increase
 - b. decrease, decrease
 - c. increase, decrease
 - d. decrease, increase

8. See Figure 14-1. Find the current.
- 107 mA
 - 240 mA
 - 120 mA
 - 60 mA

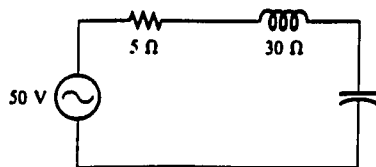


FIGURE 14-2

9. See Figure 14-2. At resonance the current will be
- 10 A
 - 10 mA
 - 1.66 A
 - 1.66 mA
10. See Figure 14-2. The voltage across the resistor at resonance is
- 49.8 V
 - 49.8 mV
 - 50 mV
 - 50 V
11. See Figure 14-2. At resonance, the voltage across the capacitor is
- 300 mV
 - 300 V
 - 30 V
 - 3 V
12. In a resonant parallel RLC circuit, the impedance is _____ and the total current is _____.
- maximum, maximum
 - minimum, minimum
 - maximum, minimum
 - minimum, maximum
13. A resonant circuit with a high Q means that it
- has a narrow pass band.
 - tunes broadly.
 - has a small voltage across the capacitor.
 - has a wide pass band.

14. The resonant frequency of a tank circuit with $L = 150 \mu\text{H}$ and with $C = 300 \text{ pF}$ is
a. 1.65 MHz
b. 751 kHz
c. 347 kHz
d. 6.05 MHz
15. What is the bandwidth of a circuit resonant at 500 kHz, if $X_L = 2.5 \text{ k}\Omega$ and the coil resistance is 25Ω ?
a. 100 Hz
b. 1000 Hz
c. 2.5 kHz
d. 5 kHz
16. A circuit is resonant at 1 MHz. If $Q = 50$, then $f_1 = \underline{\hspace{2cm}}$ and $f_2 = \underline{\hspace{2cm}}$.
a. 0.98 MHz, 1.01 MHz
b. 0.99 MHz, 1.02 MHz
c. 0.99 MHz, 1.01 MHz
d. 0.98 MHz, 1.02 MHz
17. The impedance of a parallel resonant circuit is $50 \text{ k}\Omega$. The impedance of the circuit at the lower cutoff frequency is
a. 385 $\text{k}\Omega$
b. 35.35 $\text{k}\Omega$
c. 35.35 kHz
d. Unable to be computed, since there is not enough data.
18. The input voltage to a series resonant circuit is 120 mV. The output voltage across the inductor is 12.7 V. What is the voltage ratio of V_o to V_{in} expressed in decibels?
a. 105.8 dB
b. 20.2 dB
c. 40.4 dB
d. -19.5 dB
19. A resonant circuit is delivering 50 W of power. The power at the upper cutoff frequency is
a. 25 W
b. 35.35 W
c. 50 W
d. 70.7 W
20. A parallel resonant circuit has an X_L of 502Ω . The source voltage is 25 V at a frequency of 14.9 MHz and $Q = 55$. What is the tank current?
a. 270 mA
b. 49.8 mA
c. 9.12 mA
d. 20.08 mA

CHAPTER 15 QUIZ

Student Name _____

1. In an RC integrating circuit, the output is taken across the resistor.
 - a. true
 - b. false
 2. In an integrator, when the pulse width of the input is much greater than 5τ , the output approaches the shape of the input.
 - a. true
 - b. false
 3. In an RL integrating circuit, the output is taken across the resistor.
 - a. true
 - b. false
 4. It takes a capacitor one time constant to completely charge.
 - a. true
 - b. false
 5. An RC differentiating circuit has the output taken from across the capacitor.
 - a. true
 - b. false
 6. An integrating circuit has $R = 4.7 \text{ k}\Omega$ in series with $C = 0.005 \text{ }\mu\text{F}$. What is the time constant?
 - a. $23.5 \text{ }\mu\text{s}$
 - b. 2.35 ms
 - c. 0.0235 ms
 - d. 0.00235 ms
 7. An integrating circuit has $R = 100 \text{ k}\Omega$ and $C = 22 \text{ }\mu\text{F}$. What is the time constant?
 - a. 2.2 ms
 - b. $2.2 \text{ }\mu\text{s}$
 - c. 2.2 s
 - d. 22 s
 8. A $5.1\text{-M}\Omega$ resistor is in series with a 100-pF capacitor. How long will it take to completely charge the capacitor?
 - a. 25.5 s
 - b. 2.55 s
 - c. 255 ms
 - d. 2.55 ms
-

9. A $100\text{-}\mu\text{F}$ capacitor is charged to 75 V. You discharge it through a $47\text{-k}\Omega$ resistor. How long will it take to completely discharge?
- 4.7 s
 - 23.5 s
 - 47.6 s
 - 75 s
10. A 12-V pulse is applied to an RC integrator. The pulse width equals one time constant. What will the voltage across the capacitor be at the end of the pulse?
- 4.41 V
 - 12 V
 - 7.58 V
 - 0 V
11. An RC integrator circuit has a $C = 0.05\text{ }\mu\text{F}$ and $R = 22\text{ k}\Omega$. A single pulse of 12 V is applied to the circuit. The pulse width is 2.2 ms. Determine the capacitor voltage at the end of the pulse.
- 10.38 V
 - 12 V
 - 7.58 V
 - 4.42 V
12. An RC integrator has $C = 47\text{ }\mu\text{F}$ and $R = 12\text{ k}\Omega$. A square wave input with a frequency of 200 kHz is applied. The approximate output of the circuit is
- a square wave with a frequency of 100 kHz.
 - 0 V.
 - a square wave with a frequency of 200 kHz.
 - a near dc voltage of about half the peak square wave voltage.
13. An RC differentiator circuit has $C = 47\text{ }\mu\text{F}$ and $R = 12\text{ k}\Omega$. The input signal is a square wave with a very short pulse width compared to the time constant. The output signal will be
- a dc value of about half the peak input voltage.
 - a square wave very similar to the input voltage.
 - a dc voltage level equal to the peak input voltage.
 - zero volts.
14. An RL integrator has the output taken _____ the _____.
- across, resistor
 - across, inductor
 - across, resistor and inductor
 - in parallel with, inductor

15. You want to fully charge a 200- μF capacitor in 12 s. What size resistor should you use?
 - a. 60 $\text{k}\Omega$
 - b. 12 $\text{k}\Omega$
 - c. 6 $\text{k}\Omega$
 - d. 1.2 $\text{k}\Omega$
 16. A 47- μF capacitor is in series with a 12- $\text{k}\Omega$ resistor. A pulse of 12 V is applied for 2.256 s. What is the voltage across the capacitor?
 - a. 7.58 V
 - b. 10.38 V
 - c. 11.4 V
 - d. 12 V
 17. An RL integrator circuit has $L = 10 \text{ mH}$ and $R = 10 \Omega$. A pulse with a peak voltage of 16 V is applied for 1 ms. What is the output voltage?
 - a. 10.11 V
 - b. 13.84 V
 - c. 15.2 V
 - d. 16.32 V
 18. An RL integrator has $R = 25 \Omega$ and $L = 200 \mu\text{H}$. A pulse with a peak voltage of 25 V is applied for 16 μs . What is the output voltage?
 - a. 15.63 V
 - b. 21.63 V
 - c. 23.75 V
 - d. 25 V
 19. You decide to compare an RC integrator to an RL integrator. You put the same square wave signal into both circuits. The results
 - a. indicate opposite action.
 - b. indicate a higher voltage out from the RC integrator.
 - c. indicate a higher voltage out from the RL integrator.
 - d. indicate the exact same output from both circuits.
 20. An RC integrator circuit can be used for
 - a. obtaining good dc output.
 - b. wave-shaping input waveforms.
 - c. timing circuits with pulse inputs.
 - d. all of the above.
-

APPENDIX F: POSTTEST (MIDTERM EXAMINATION)

10/8/92 & 10/9/92
 Saeid Moslehpour
 IEDT 140 Basic Electronics

MIDTERM

Name _____

Read each question carefully before you answer. Work at a steady pace, and you should have ample time to finish. Make sure your name is on your paper before you turn it in.

1. 0.0047 amps can be expressed in metric units as 47 μ A.
 a. True b. False
2. The symbol μ is an abbreviation for 10^{-6} or micro.
 a. True b. False
3. 0.00015 volts can be expressed in powers of ten as 1.5×10^{-4} .
 a. True b. False
4. Express 5.6×10^{-2} in milli, basic units, and micro.

a. 5.6 milli	0.056	56000
b. 56 milli	0.056	56000
c. 560 milli	5.6 00	5600
d. 5600 milli	56	560
5. You have just calculated an answer for a problem. Your calculator reads 3.5-06. The correct metric value is

a. 35 milli	d. 3.5 micro
b. 35 micro	e. 3.5 pico
c. 3.5 Meg	
6. A device that stores energy electromagnetically is

a. a capacitor	c. a transistor
b. an inductor	d. a diode
7. An electronic device that stores electric charge is

a. a transformer	d. an inductor
b. a capacitor	e. a semiconductor
c. a resistor	
8. An electronic device that resists the flow of current in a circuit is known as

a. a capacitor	c. a resistor
b. an inductor	d. a transformer
9. A typical semiconductor device is

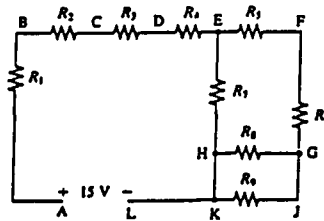
a. the transformer.	c. the resistor.
b. the diode.	d. the capacitor.
10. An electrical symbol for voltage is

a. I	c. C
b. V	d. R
11. A normally open push button switch could have current through it when not being pushed.
 a. True b. False

MIDTERM Page 2

12. A resistor color coded with bands of yellow, violet, and orange has a value of $4.7 \text{ k}\Omega$.
 a. True b. False
13. A SPST switch is used to control one circuit.
 a. True b. False

 Please refer to Figure 2-2 below:

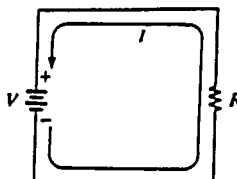


14. See figure 2-2. To measure the current that flows through R_6 , the circuit must be opened and the ammeter placed at point
 a. E c. G
 b. F d. H
15. See figure 2-2. The measured voltage V_{JK} is the same as
 a. V_{R5} c. V_{R7}
 b. V_{R6} d. V_{R8}
16. See figure 2-2. The measured voltage V_{FG} is the same as
 a. V_{R6} c. V_{R8}
 b. V_{R7} d. V_{R9}
17. See figure 2-2. Voltmeter leads placed across points C and D will read
 a. V_{R1} c. V_{R3}
 b. V_{R2} d. V_{R4}
18. See figure 2-2. The measured voltage V_{CE} is the same as
 a. V_{R5} c. $V_{R4} + V_{R5}$
 b. $V_{R3} + V_{R4}$ d. V_{R6}
19. An analog meter has
 a. a digital readout.
 b. a needle and a scale to indicate the value.
 c. no moving parts.
20. An analog ohmmeter should
 a. be connected across a circuit with the power on.
 b. be inserted into the circuit so the current flows through it.
 c. placed across the resistance after the resistance is opened.
 d. have the polarity carefully checked before its use.
21. A circuit has a supply voltage of 15 V. The resistance is 4700Ω . The current is 313 mA.
 a. True b. False

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22. A 1 k Ω resistor has 32 mA flowing through it. The resistor is dissipating 1.024 W.
a. True b. False
23. A 47 k Ω resistor has 5 mA flowing through it. It is OK to use a resistor with a power rating of 1 W.
a. True b. False

Please refer to Figure 3-1 below:

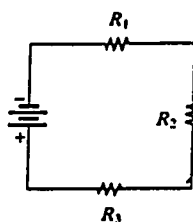


24. See figure 3-1. If $V = 50$ V, and $R = 25$ k Ω , the current equals
a. 50 mA c. 0.5 mA
b. 5 mA d. 2 mA
25. See figure 3-1. If $I = 64$ mA, and $R = 47$ Ω , the voltage equals
a. 30.08 V c. 73.43 V
b. 3.008 V d. 7.343 V
26. See figure 3-1. If $V = 85$ V, and $I = 15$ mA, the resistance equals
a. 1.275 Ω c. 5.667 k Ω
b. 52.3 Ω d. 566 Ω
27. See figure 3-1. If $V = 50$ V, and $I = 37$ mA, the power dissipated by the resistor is
a. 1.85 W c. 0.185 mW
b. 1.35 W d. 135 mW
28. A 150 W lightbulb has a resistance measurement of 75 Ω when out of the circuit. What is the resistance of the bulb when it is energized and in a circuit with a supply of 125 V?
a. 75 Ω c. 9375 Ω
b. 104 Ω d. 2.14 Ω
29. Which is the correct formula for finding power?
a. $P = VI$ c. $P = V^2/R$
b. $P = I^2R$ d. all of these
30. A resistor color coded red, red, brown, and silver is connected to a 15 V source. If the resistor is within tolerance, what is the maximum current that will flow?
a. 75.8 mA c. 64.9 mA
b. 62 mA d. 71.9 mA
31. Three resistors, 4.7 k Ω , 2.2 k Ω , and 1.2 k Ω are in series. The total resistance is 8.7 k Ω .
a. True b. False

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32. A resistor is rated at $1/2$ W. This resistor can safely dissipate 0.325 W.
 a. True b. False
33. The total power dissipated in a series circuit is equal to the source voltage multiplied by the current.
 a. True b. False

 Please refer to Figure 4-1 below:



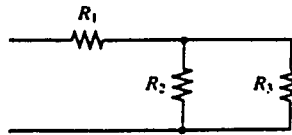
34. See figure 4-1. $R_1 = 4.7 \text{ k}\Omega$, $V_{R1} = 10 \text{ V}$, $R_2 = 4.7 \text{ k}\Omega$, and $R_3 = 4.7 \text{ k}\Omega$. Calculate the voltage drops across R_2 and R_3 .
 a. $V_{R2} = 10 \text{ V}$ $V_{R3} = 10 \text{ V}$
 b. $V_{R2} = 4.7 \text{ V}$ $V_{R3} = 10 \text{ V}$
 c. $V_{R2} = 10 \text{ V}$ $V_{R3} = 4.7 \text{ V}$
 d. $V_{R2} = 14.7 \text{ V}$ $V_{R3} = 14.7 \text{ V}$
35. See figure 4-1. $R_1 = 4.7 \text{ k}\Omega$, $V_{R1} = 10 \text{ V}$, $R_2 = 4.7 \text{ k}\Omega$, and $R_3 = 4.7 \text{ k}\Omega$. Calculate the circuit current.
 a. 1 mA c. 4.26 mA
 b. 2.13 mA d. 6 mA
36. See figure 4-1. $R_1 = 4.7 \text{ k}\Omega$, $V_{R1} = 10 \text{ V}$, $R_2 = 4.7 \text{ k}\Omega$, and $R_3 = 4.7 \text{ k}\Omega$. Calculate the source voltage.
 a. 4.7 V c. 14.7 V
 b. 10 V d. 30 V
37. See figure 4-1. If R_2 shorts, the total power dissipated in the circuit will
 a. increase.
 b. decrease.
 c. remain the same.
 d. be dependent upon the source voltage.
38. See figure 4-1. $R_1 = 4.7 \text{ k}\Omega$, $V_{R1} = 10 \text{ V}$, $R_2 = 4.7 \text{ k}\Omega$, and $R_3 = 4.7 \text{ k}\Omega$. The total circuit resistance if R_2 shorts is
 a. 0 Ω c. 9.4 $\text{k}\Omega$
 b. 4.7 $\text{k}\Omega$ d. infinite Ω
39. Two power supplies are in series with voltages of 18 V and - 6 V respectively. What is the total supply voltage?
 a. -12 V c. 18 V
 b. 6 V d. 12 V

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40. Two sources, -12 V and -6 V are connected so the total voltage is -18 V . These sources are said to be
 - a. series aiding.
 - b. series opposing.
 - c. in parallel.
 - d. dangerous to connect.
41. Three equal resistors are connected in parallel. The source voltage is 12 V . The voltage across each resistor is 4 V .
 - a. True
 - b. False
42. A parallel branch has 0.065 mA flowing and the other branch has 0.098 mA flowing. The total current is 0.163 mA .
 - a. True
 - b. False
43. Two resistors are in parallel. One is dissipating 0.25 W and the other is dissipating 1.2 W . The total power dissipated is 1.25 W .
 - a. True
 - b. False
44. Three resistors are connected in parallel. The values are $2.2\text{ k}\Omega$, $10\text{ k}\Omega$, and $1.2\text{ k}\Omega$. What is R_T ?
 - a. $721\text{ }\Omega$
 - b. $13.4\text{ k}\Omega$
 - c. $2.27\text{ k}\Omega$
 - d. $1.2\text{ k}\Omega$
45. Three resistors, $470\text{ }\Omega$, $680\text{ }\Omega$, and $830\text{ }\Omega$ are connected in parallel. That is R_T ?
 - a. $1980\text{ }\Omega$
 - b. $1510\text{ }\Omega$
 - c. $1150\text{ }\Omega$
 - d. $208\text{ }\Omega$
46. Two resistors are in parallel, $4.7\text{ k}\Omega$ and $2.2\text{ k}\Omega$. The total resistance of the circuit is
 - a. $2200\text{ }\Omega$
 - b. $4700\text{ }\Omega$
 - c. greater than $2200\text{ }\Omega$
 - d. less than $2200\text{ }\Omega$
47. A parallel circuit consists of $R_1 = 1.2\text{ M}\Omega$, $R_2 = 1\text{ M}\Omega$, and R_3 . If $R_T = 0.5\text{ M}\Omega$, find R_3 .
 - a. $6\text{ M}\Omega$
 - b. $1.7\text{ M}\Omega$
 - c. $2\text{ M}\Omega$
 - d. $7.7\text{ M}\Omega$
48. Three resistors are connected in parallel across a source of 15 V . The values are $5.2\text{ M}\Omega$, $1.2\text{ M}\Omega$, and $1\text{ M}\Omega$. If the $1.2\text{ M}\Omega$ resistor opens, the total current will be
 - a. $2.88\text{ }\mu\text{A}$
 - b. $17.88\text{ }\mu\text{A}$
 - c. $12.5\text{ }\mu\text{A}$
 - d. $2.41\text{ }\mu\text{A}$
49. Eight $47\text{ k}\Omega$ resistors are connected in parallel across 25 V . What is R_T ?
 - a. $376\text{ k}\Omega$
 - b. $6.71\text{ k}\Omega$
 - c. $5.875\text{ k}\Omega$
 - d. $4.7\text{ k}\Omega$
50. A circuit with three resistors in parallel has a total current of 1.2 mA . If $I_1 = 0.2\text{ mA}$, and $I_2 = 0.7\text{ mA}$, find I_3 .
 - a. 2.4 mA
 - b. 0.3 mA
 - c. 7.2 mA
 - d. 8.7 mA

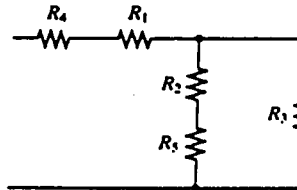
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Please refer to Figure 6.1 below:



51. See figure 6-1. R_2 is in parallel with R_3 .
 a. True b. False
52. See figure 6-1. R_1 is in series with R_3 .
 a. True b. False
53. See figure 6-1. R_1 is in series with the parallel combination R_2 and R_3 .
 a. True b. False

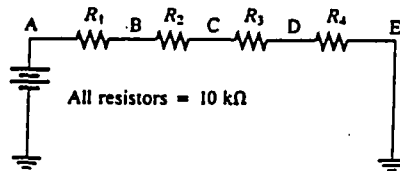
Please refer to Figure 6-2 below:



54. See figure 6-2. If all of the resistors have a value of $2.2\text{ k}\Omega$, find R_T .
 a. $5.87\text{ k}\Omega$ c. $4.4\text{ k}\Omega$
 b. $5.5\text{ k}\Omega$ d. $2.2\text{ k}\Omega$
55. See figure 6-2. If all of the resistors equal $2.2\text{ k}\Omega$ and the source voltage is 15 V , find I_{R_2} .
 a. 2.55 mA c. 0.85 mA
 b. 5.11 mA d. 0.42 mA
56. See figure 6-2. R_1 , R_2 , and R_3 equal $4.7\text{ k}\Omega$. R_4 and R_5 equal $10\text{ k}\Omega$. Find R_T .
 a. $6.1\text{ k}\Omega$ c. $24.7\text{ k}\Omega$
 b. $18.3\text{ k}\Omega$ d. $34.1\text{ k}\Omega$

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Please refer to Figure 6-3 below:



57. See figure 6-3. The resistance between points A and D is
 - a. 10 kΩ
 - b. 20 kΩ
 - c. 30 kΩ
 - d. 40 kΩ
58. See figure 6-3. If $V_{R1} = 15$ V, find V_{BD} .
 - a. 60 V
 - b. 45 V
 - c. 30 V
 - d. 15 V
59. See figure 6-3. If the source voltage equals 50 V, find V_{CA} .
 - a. 5 V
 - b. 25 V
 - c. -5 V
 - d. -25 V
60. See figure 6-3. If the source voltage is 40 V and R_3 opens, find V_{R3} .
 - a. 0 V
 - b. 10 V
 - c. 20 V
 - d. 30 V
 - e. 40 V
61. See figure 6-3. If another 10 kΩ resistor were placed in series with R_1 , the voltage across R_4 would
 - a. increase
 - b. decrease
 - c. remain the same
 - d. increase to 10 V
62. See figure 6-3. The current is measured at 12 mA. Find V_{EB} .
 - a. 120 V
 - b. -360 V
 - c. -240 V
 - d. 240 V
63. See figure 6-3. The measured current is 1.2 mA. Find the power dissipated in the circuit.
 - a. 0.576 mW
 - b. 5.76 mW
 - c. 57.6 mW
 - d. 576 mW
64. See figure 6-3. $V_{R3} = 17$ V, find P_1 .
 - a. 1.7 mW
 - b. 28.9 mW
 - c. 2.89 W
 - d. 17 mW
65. See figure 6-2. If R_2 shorts, V_{R3} will
 - a. increase
 - b. decrease
 - c. remain the same

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66. See figure 6-1. If $R_1 = 10 \text{ k}\Omega$, $R_2 = 15 \text{ k}\Omega$, and $R_3 = 50 \text{ k}\Omega$, find R_T .
- | | |
|--------------------|-------------------|
| a. 21.5 k Ω | c. 10 k Ω |
| b. 11.5 k Ω | d. 9.5 k Ω |
67. Soft iron has a high
- | | |
|-----------------|---------------|
| a. mmf | c. resistance |
| b. permeability | d. reactance |
68. Magnetic lines that are close to each other are said to have a high
- | | |
|----------------|------------------|
| a. reluctance. | c. flux density. |
| b. inductance. | d. current. |
69. The permeability of air is said to be
- | | |
|------|---------|
| a. 1 | c. 19.2 |
| b. 7 | d. 22 |
70. A solenoid consists of
- | |
|------------------------------------------|
| a. two plates separated by an insulator. |
| b. a burglar alarm. |
| c. a coil of wire wound around a core. |
| d. a permanent magnet. |

APPENDIX G: FINAL EXAMINATION

May 12, 1992
 Saeid Moslehpour
 Basic Electronics IEDT140

Final Examination

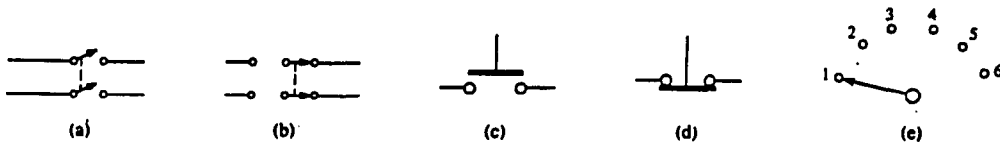
Name _____

Read each question carefully before you answer. Work at a steady pace, and you should have ample time to finish. Make sure your name is on your paper before you turn it in.

1. An electronic device that stores electric charge is
 - a. a transformer
 - b. a capacitor
 - c. a resistor
 - d. an inductor
 - e. a semiconductor
2. You have just calculated an answer for a problem. Your calculator reads 3.5-06. The correct metric value is
 - a. 35 milli
 - b. 35 micro
 - c. 3.5 Meg
 - d. 3.5 micro
 - e. 3.5 pico
3. Express 5.6×10^{-2} in milli, basic units, and micro.

a. 5.6 milli	0.056	56000
b. 56 milli	0.056	56000
c. 560 milli	5.6 00	5600
d. 5600 milli	56	560

 Please refer to Figure 2-1 below:



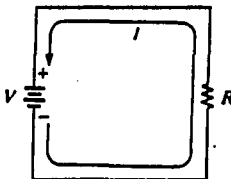
4. See figure 2-1. Identify the dpdt switch.
 - a. A
 - b. B
 - c. C
 - d. D
 - e. E
5. See figure 2-1. Which switch could be used to control a light and a fan at the same time?
 - a. A
 - b. B
 - c. C
 - d. D
 - e. E
6. See figure 2-1. Which switch could be used to switch two inputs to two different output positions?
 - a. A
 - b. B
 - c. C
 - d. D
 - e. E

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7. See figure 2-1. Which switch could be used to open a circuit momentarily?

a. A
b. B
c. C
d. D
e. E

Please refer to Figure 3-1 below:

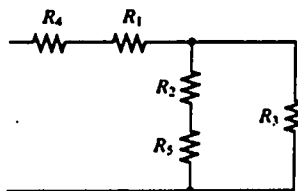


8. See figure 3-1. If $V = 60 \text{ V}$ and $R = 47 \text{ k}\Omega$; then the current equals
a. 1.27 mA
b. 12.7 mA
c. 127 mA
d. .127 mA
9. See figure 3-1. If a resistor with a power rating of $1/2 \text{ W}$ is used in this circuit, the current must be
a. over 12 mA.
b. less than 12 mA.
c. dependent upon the voltage applied.
d. dependent upon the voltage and the value of the resistor in the circuit.
10. See figure 3-1. If the voltage were suddenly switched on,
a. the current would gradually decrease.
b. the current would be zero.
c. the current would flow.
d. the current would gradually decrease and then increase.
11. See figure 3-1. If $I = 27 \text{ mA}$, and $R = 4.7 \Omega$, the voltage would equal
a. 127 mV
b. 5.74 V
c. 174 mV
d. 7.8 V
12. Two resistors are in series. $R_1 = 10 \text{ k}\Omega$ and $R_2 = 5 \text{ k}\Omega$. A source voltage of 12 V is applied. V_{R1} will be _____, and V_{R2} will be _____.
a. 8 V, 4 V
b. 4 V, 8 V
c. 8 V, 8 V
d. 4 V, 4 V
13. A series circuit with four resistors connected across a 30 V source has a current of 0.125 mA flowing through it. Three of the resistors have values of $10 \text{ k}\Omega$, $33 \text{ k}\Omega$, and $47 \text{ k}\Omega$. What is the value of the fourth resistor?
a. 150 Ω
b. 1.5 k Ω
c. 15 k Ω
d. 150 k Ω

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14. The polarity of voltages across a resistor is dependent on the current direction. The resistor end where current leaves is said to be _____, and the other end is _____.
 a. positive, positive c. negative, positive
 b. negative, negative d. positive, negative
15. A 50 k Ω potentiometer is connected across 15 V. The voltage from the wiper to the lower end of the pot is 3.2 V. What is the resistance of the lower part of the potentiometer?
 a. 10.67 k Ω c. 50 k Ω
 b. 39.3 k Ω d. 0 Ω
16. The power dissipated in any branch of a parallel circuit is
 a. dependent on the power rating of the resistor.
 b. only dependent on the circuit voltage.
 c. only dependent on the total current.
 d. dependent on the voltage and value of the resistor.
17. You have a four-resistor parallel circuit. If you want to measure the current through one of the parallel resistors with a DVM, the meter is connected
 a. in series with the resistor.
 b. across the source.
 c. in parallel with the resistor.
 d. in series with the source.
18. A parallel circuit consists of $R_1 = 10$ k Ω and R_2 . The value of R_T is 6.8 k Ω . Find R_2 .
 a. 16.8 k Ω c. 21.25 k Ω
 b. 3.2 k Ω d. 12 k Ω
19. As resistors are removed from a parallel circuit,
 a. I_T decreases and R_T increases.
 b. I_T decreases and R_T decreases.
 c. I_T increases and R_T decreases.
 d. I_T increases and R_T increases.

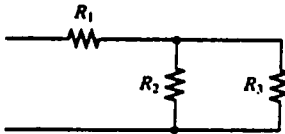
 Please refer to Figure 6-2 below:



20. See figure 6-2. If R_2 shorts, V_{R3} will
 a. increase
 b. decrease
 c. remain the same

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Please refer to Figure 6.1 below:

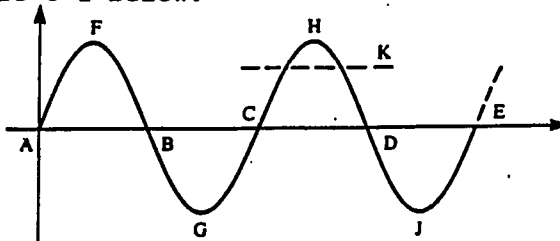


21. See figure 6-1. If $R_1 = 10\text{ k}\Omega$, $R_2 = 15\text{ k}\Omega$, and $R_3 = 50\text{ k}\Omega$, find R_T .
 - a. $21.5\text{ k}\Omega$
 - b. $11.5\text{ k}\Omega$
 - c. $10\text{ k}\Omega$
 - d. $9.5\text{ k}\Omega$
22. See figure 6-1. If $R_1 = 10\text{ k}\Omega$, $R_2 = 15\text{ k}\Omega$, and $R_3 = 50\text{ k}\Omega$, and the source voltage equals 25 V , calculate the total current.
 - a. 2.17 mA
 - b. 2.5 mA
 - c. 1.58 mA
 - d. 1.16 mA
23. If a combination of four parallel $10\text{ k}\Omega$ resistors were in series with a single $20\text{ k}\Omega$ resistor, and one of the parallel combination resistors shorted, the voltage across the other parallel resistors would
 - a. increase.
 - b. decrease.
 - c. remain the same.
24. A simple electric door bell probably uses _____ to ring the bell.
 - a. a vacuum tube
 - b. a relay
 - c. an electromagnet
 - d. a permanent magnet
25. A relay is a device that
 - a. uses an electromagnet to open and close contacts.
 - b. can be very small or very large.
 - c. that has a coil to actuate some contacts to control other circuits.
 - d. all of the above
26. Commercial line voltages are usually square waves at a frequency of 60 Hz .
 - a. True
 - b. False
27. If an ac voltage is applied to a resistor the current will increase.
 - a. True
 - b. False
28. A formula for V_{rms} is
 - a. $0.707V_{rms}$
 - b. $0.707V_p$
 - c. $2V_p$
 - d. $2.8V_p$

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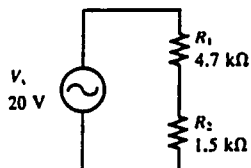
29. A sine wave has a peak value of 169 V. What is the instantaneous value at a angle of 17° from the start of a cycle?
- a. 49.4 V
 - b. 98.8 V
 - c. 161 V
 - d. 80.5 V

Please refer to Figure 8-1 below:



30. See figure 8-1. The time from point A to C is called
- a. the frequency.
 - b. V_p .
 - c. the period.
 - d. the rms voltage.

Please refer to Figure 8-2 below:



31. See figure 8-2. Find R_T .
- a. 1.13 kΩ
 - b. 4.7 kΩ
 - c. 4.77 kΩ
 - d. 6.2 kΩ
32. See figure 8-2. Solve for V_{R1p-p} .
- a. 21.44 V
 - b. 6.84 V
 - c. 42.88 V
 - d. 13.68 V
33. See figure 8-2. If R_2 shorts, V_{R2} will
- a. increase.
 - b. decrease.
 - c. remain the same.
 - d. not change since the source is ac.
34. See figure 8-2. Find the instantaneous voltage of R_1 at an angle of 122° .
- a. 18.18 V
 - b. 5.8 V
 - c. 11.15 V
 - d. 11.6 V
35. The vertical deflection of a scope trace is 1.6 cm. The volts/division switch is set on 50 mV/cm. The voltage is
- a. 80 mV
 - b. 50 mV
 - c. 1.6 mV
 - d. 0.008 V

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36. If the area of the plates of a capacitor is decreased, then the capacitance will decrease.
a. True b. False
37. The time constant is the time required for a capacitor to fully charge.
a. True b. False
38. A capacitor has a charge of $1.175 \mu\text{C}$ and a voltage of 25 V across it. What is the capacitance?
a. $0.047 \mu\text{F}$ c. $4.7 \mu\text{F}$
b. $0.47 \mu\text{F}$ d. $47 \mu\text{F}$
39. A $0.47 \mu\text{F}$ capacitor has a voltage across it of 18 V. What charge is stored in the capacitor?
a. $846 \mu\text{F}$ c. $8.46 \mu\text{F}$
b. $84.6 \mu\text{F}$ d. $0.846 \mu\text{F}$
40. A capacitor is to be used in a circuit where the ac voltage is 120 V. What should the dc working voltage of the capacitor be?
a. 120 V c. 84.8 V
b. 169 V d. 339 V
41. Three capacitors are in series. $C_1 = 0.047 \mu\text{F}$, $C_2 = 0.047 \mu\text{F}$, $C_3 = 0.47 \mu\text{F}$, and the source voltage is 25 V. What is C_T and the voltage across C_2 .
a. $0.022 \mu\text{F}$ and 11.9 V c. $0.564 \mu\text{F}$ and 1.2 V
b. $0.022 \mu\text{F}$ and 25 V d. $0.564 \mu\text{F}$ and 11.9 V
42. Two capacitors are connected in parallel across a 15 V source. $C_1 = 22 \mu\text{F}$ and $C_2 = 100 \mu\text{F}$. Find C_T and the voltage across C_1 .
a. $18 \mu\text{F}$ and 15 V c. $122 \mu\text{F}$ and 15 V
b. $18 \mu\text{F}$ and 5.2 V d. $1220 \mu\text{F}$ and 30 V
43. A $47 \mu\text{F}$ capacitor is in series with a $120 \text{ k}\Omega$ resistor. What is the time constant?
a. 0.564 ms c. 5.64 s
b. 564 ms d. 54.6 s
44. A $22 \mu\text{F}$ capacitor is in series with a $47 \text{ k}\Omega$ resistor. How long will it take for the capacitor to completely charge?
a. 1.034 s c. 8.272 s
b. 2.068 s d. 5.17 s
45. A $22 \mu\text{F}$ capacitor is in series with a $4.7 \text{ k}\Omega$ resistor. How long will it take for the capacitor to completely discharge through the resistor?
a. 0.827 s c. 0.207 s
b. 0.517 s d. 0.103 s
46. If an inductor is placed in a circuit with ac applied, the voltage across the inductor leads the current through it.
a. True b. False

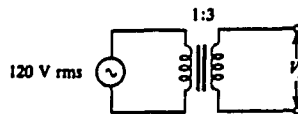
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47. When a dc voltage is first applied to an inductor, the circuit current is zero.
a. True b. False
48. Two identical inductors A and B have different currents through them. Inductor A's current is the larger. Which inductor has the greatest inductance?
a. A
b. B
c. both have the same
49. Three inductors are in series. $L_1 = 14 \text{ mH}$, $L_2 = 22 \text{ mH}$, and $L_3 = 45 \text{ mH}$. Determine the total inductance.
a. $81 \mu\text{H}$ c. 81 mH
b. 7.2 mH d. 20 mH
50. A 50 mH inductor is in series with a $50 \text{ k}\Omega$ resistor. The source voltage is 50 V . What is the maximum current that will flow in the circuit?
a. $1 \mu\text{A}$ c. 1 mA
b. $100 \mu\text{A}$ d. 10 mA
51. A 25 mH inductor has a voltage of 50 V with a frequency of 400 Hz applied to it. Find X_L .
a. 62.8Ω c. $6.28 \text{ k}\Omega$
b. 628Ω d. $62.8 \text{ k}\Omega$
52. A $15 \mu\text{H}$ inductor is applied in a circuit. The X_L of the inductor is $2.2 \text{ k}\Omega$. Determine the operating frequency.
a. 23.4 kHz c. 4.28 MHz
b. 23.4 MHz d. 4.28 kHz
53. An inductor has a dc voltage applied to it. How many time constants will it take to completely build the magnetic field around it?
a. 1 d. 4
b. 2 e. 5
c. 3
54. A $100 \mu\text{H}$ inductor with a resistance of 12Ω is supplied with a source with a frequency of 100 kHz . What is X_L ?
a. $62.8 \text{ k}\Omega$ c. 6.28Ω
b. 62.8Ω d. infinite
55. An inductor is in a circuit with a voltage of 25 V . The current is 1.25 mA and the frequency is 100 Hz . What is X_L ?
a. 31.25Ω c. $3.125 \text{ k}\Omega$
b. $15.7 \text{ k}\Omega$ d. 20Ω
56. If a dc voltage is applied to the primary of a transformer, an ac voltage is induced in the secondary.
a. True b. False
57. A transformer with a turns ratio of $1:7$ is a step down transformer.
a. True b. False

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58. When a 12 V battery is connected across the primary of a transformer with a turns ratio of 1:4, the secondary voltage is
- 0 V
 - 12 V
 - 48 V
 - 3 V

Please refer to Figure 11-1 below:

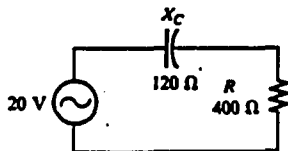


59. See figure 11-1. If there are five times more turns in the primary than in the secondary, what is the secondary voltage?
- 600 V
 - 120 V
 - 24 V
 - 12 V
60. See figure 11-1. If the ratio of primary to secondary turns is changed to 9:1, what is the output voltage V_s ?
- 13.3 V
 - 26.6 V
 - 53.2 V
 - 106 V
61. See figure 11-1. If the primary to secondary turns ratio is changed to 4:1, and a load resistor of 1 k Ω is in the secondary, what is the secondary current I_s ?
- 480 mA
 - 240 mA
 - 120 mA
 - 30 mA
62. See figure 11-1. The primary to secondary turns ratio is 1:3 and $I_s = 120$ mA. What is the primary current I_p ?
- 360 mA
 - 40 mA
 - 180 mA
 - cannot compute because the voltage is not given
63. See figure 11-1. The primary to secondary turns ratio is changed to 2.5:1 and $I_s = 100$ mA. What is the reflected resistance seen by the primary?
- 1.2 k Ω
 - 2.5 k Ω
 - 3 k Ω
 - 5 k Ω
64. A circuit is giving you problems. The power transformer is delivering zero output volts. The input voltage to the primary is correct. A probable trouble is
- an partially shorted secondary.
 - an open primary.
 - a shorted primary.
 - a partially shorted primary.

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65. You are going to buy a matching transformer to match a $600\ \Omega$ audio load to a $4\ \Omega$ speaker system. The primary should have _____ more turns than the secondary.
- 12.24
 - 150
 - 3.06
 - The primary should have less turns than the secondary.
66. The total current in an RC circuit always lags the source voltage.
- True
 - False
67. The phasor combination of X_C and R is called Z .
- True
 - False

Please refer to Figure 12-1 below:

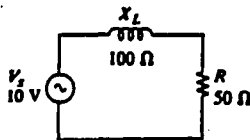


68. See figure 12-1. If the frequency is 400 Hz, what is the value of capacitance?
- $3.3\ \mu\text{F}$
 - $6.6\ \mu\text{F}$
 - $8.8\ \mu\text{F}$
 - $10\ \mu\text{F}$
69. See figure 12-1. If the source voltage is changed to 100 V, find the impedance.
- $120\ \Omega$
 - $280\ \Omega$
 - $418\ \Omega$
 - $520\ \Omega$
70. See figure 12-1. If the source voltage is changed to 100 V, calculate the true power.
- 22.9 W
 - 22.9 mW
 - 3.66 W
 - 11 W
71. See figure 12-1. If the operating frequency is decreased, what effect will that decrease have on the current? It will
- increase.
 - remain the same.
 - decrease.
 - decrease to zero.
72. See figure 12-1. If the operating frequency is decreased, what effect will that decrease have upon the phase angle? It will
- increase.
 - remain the same.
 - decrease.
 - change to another quadrant.
73. See figure 12-1. If the operating frequency is decreased, what effect will that decrease have upon the value of the capacitor? It will
- increase.
 - remain the same.
 - decrease.
 - change to another quadrant.

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74. See figure 12-1. If the operating frequency is decreased, what effect will it have on the value of the resistor? It will
 a. increase. c. decrease.
 b. remain the same. d. open.
75. See figure 12-1. If the resistor is changed to 2.2 k Ω , what effect will that change have upon the total current? It will
 a. increase. c. decrease.
 b. remain the same. d. decrease to zero.
76. The impedance of an RL series circuit varies inversely with the frequency.
 a. True b. False
77. The impedance of a series RL circuit is found by adding the values of X_L and R.
 a. True b. False
78. The cutoff frequency of a high-pass RL filter is 55 kHz. The filter's bandwidth is
 a. 55 kHz c. 0 kHz
 b. 110 kHz d. unknown

 Please refer to Figure 13-1 below:

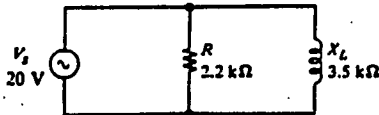


79. See figure 13-1. If the frequency is changed to 400 Hz, what is the value of the inductance?
 a. 39.8 mH c. 25.12 mH
 b. 39.8 H d. 25.12 H
80. See figure 13-1. If the source voltage is changed to 100 V, find the impedance.
 a. 104 Ω c. 1.12 k Ω
 b. 112 Ω d. 1.04 k Ω
81. See figure 13-1. If the source voltage were changed to 100 V, calculate the true power.
 a. 40 mW c. 16 W
 b. 4 W d. 40 W
82. See figure 13-1. If the operating frequency is decreased, the current will
 a. increase c. remain the same
 b. decrease d. decrease to zero

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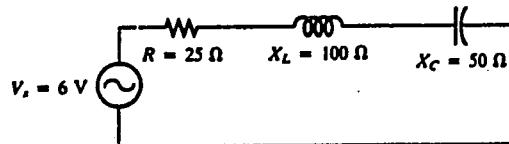
83. See figure 13-1. If the operating frequency is decreased, the phase angle will
 a. increase. c. remain the same.
 b. decrease d. change to another quadrant.
84. See figure 13-1. If the operating frequency is decreased, the value of inductance will
 a. increase. c. remain the same.
 b. decrease d. decrease to zero.

 Please refer to Figure 13-2 below:



85. See figure 13-2. If the value of the resistor is changed to 1.5 kΩ, the total current will
 a. increase. c. remain the same.
 b. decrease. d. decrease to zero.
86. At resonance, a series RLC circuit has an impedance equal to the resistance.
 a. True b. False
87. A parallel resonant circuit has minimum impedance and maximum line current.
 a. True b. False

 Please refer to Figure 14-1 below:

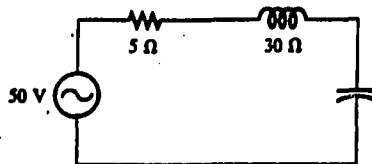


88. See figure 14-1. If you desired to operate this circuit at a frequency above resonance, you would _____ the resistance and _____ the frequency.
 a. increase, increase c. not change, increase
 b. decrease, decrease d. not change, decrease
89. See figure 14-1. If the frequency of the source voltage is decreased, the impedance will _____ and the current will _____.
 a. decrease, decrease c. increase, increase
 b. decrease, increase d. increase, decrease

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90. See figure 14-1. If the resistance R were decreased, the impedance would
- increase
 - decrease
 - remain the same
 - become zero

Please refer to Figure 14-2 below:



91. See figure 14-2. If the value of R were decreased, the bandwidth would
- increase.
 - remain the same.
 - decrease.
 - vary.
92. See figure 14-2. If the resistor shorts, the current would
- increase.
 - not change.
 - decrease.
 - continue but the circuit would not be resonant.
93. A resonant circuit with a high Q means that it
- has a very wide pass-band.
 - tunes sharply.
 - has no pass-band.
 - has a small voltage across the capacitor.
94. The resonant frequency of a tank circuit with $L = 150 \text{ mH}$ and $C = 300 \text{ pF}$ is
- 23.7 Hz
 - 23.7 kHz
 - 237 kHz
 - 2.37 MHz
95. What is the bandwidth of a circuit resonant at 1.42 MHz, if $X_C = 3.5 \text{ k}\Omega$ and the coil resistance is 8 ohm?
- 3.245 kHz
 - 2285 Hz
 - 1.42 MHz
 - 32.5 kHz
96. An RC integrating circuit has a 22 k Ω resistor in series with a 0.02 μF capacitor. What is the time constant?
- 0.044 ms
 - 0.044 μs
 - 0.44 ms
 - 0.44 s
97. An integrating circuit has a 10 k Ω resistor in series with a 220 μF capacitor. What is the time constant?
- 2.2 ms
 - 22 ms
 - 0.22 ms
 - 2.2 s

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98. A $5.2\text{ M}\Omega$ resistor is in series with a $0.22\text{ }\mu\text{F}$ capacitor. How long will it take to completely charge the capacitor? The source voltage is 12 V.
- | | |
|------------|------------|
| a. 5.72 s | c. 2.288 s |
| b. 1.144 s | d. 4.576 s |
99. A $0.47\text{ }\mu\text{F}$ capacitor is charged to 15 V. You discharge it through a $10\text{ k}\Omega$ resistor. How long will it take to completely discharge the capacitor?
- | | |
|------------|------------|
| a. 2.35 s | c. 23.5 ms |
| b. 0.47 ms | d. 0.18 ms |
100. A 30 V pulse is applied to an RC integrator. The pulse width equals one time constant. Find V_C at the end of the pulse.
- | | |
|------------|-----------|
| a. 18.96 V | c. 28.5 V |
| b. 25.95 V | d. 29.4 V |